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ABSTRACT

Supply chain visibility (SCV) is much sought after in supply chain management, yet SCV remains an intangible topic with no tangible artifacts. The on-demand visibility view required of one decision maker, the *seeing role*, in a supply chain is quite different to any others – context specific, and managerial varied. Data available for the view must be collected and captured by the *being seen* role with on-target provenance. IoT technology becomes an integrative glue in supply chain integration fabrics, facilitating on-target design with manageable end-to-end visibility. In this paper, we propose a duality SCV framework to operationalize visibility. Contributions of the paper are firstly to bring current SCV discussions into focus to how IoT technology deployment can be formulated with on-target precision by the *being seen*, and secondly to extend to how on-demand supply chain visibility to the *seeing* is enabled anywhere anytime.

Keywords: IoT, supply chain visibility, SCOR, RFID

INTRODUCTION

Visibility in supply chains is much sought after. Yet, a common approach to systemic enabling SCV is missing, notwithstanding the definition of SCV [15] [16]. With advances in IoT technologies, coupled with service-based ICT, the ability to deliver SCV with clarity and fidelity has become possible. Internet of Things (IoT) is a continuing development of interconnecting identifiable objects through networks. IoT technology brings real-time operational data to information flow, enriches and aligns the traditional transactional data pool with accuracy and currency. However, IoT and big data in general require us to rekindle how to deal with SCV, as big data is taking the data volume, velocity, variety, and veracity to a whole new dimension.

To put SCV in effect, a design will have to consider inherent properties of supply chains. In general, SCV involves two parties, the one being seen and the one seeing. Current literature often only focuses on the prior party and associates more information sharing with better supply chain performance. However, literature often does not investigate how SCV can actually benefit the latter party. Thus although SCV has been widely discussed, we posit that there is still a need to further study and define SCV. We propose a SCV conceptualization, which articulates SCV from both the seeing and being seen perspective.

In this paper, we provide a discernable understanding of visibility in the context of supply chains. We first define SCV and describe its dimensional characteristics. We then illustrate how SCV can be operationalized following a design science research approach. The artifact, a SCV IoT framework, guides how to deploy IoT technology in a supply chain with an on-target conceptual articulation. With that, a technological framework is offered to enable on-demand visibility by any participants of the supply chain at anytime and anywhere. Concluding remarks will be provided at the last section.

LITERATURE REVIEW: SUPPLY CHAIN VISIBILITY & IOT

Supply Chain Visibility

Views on SCV are varied and diverse. Wei and Wang 0 argue how information can be shared to benefit supply chain partners. Roh et al. 0 put emphasis on being able to timely access product information across the supply chain. Literature recognizes that SCV is important and is even considered as a top concern [3]. It is in general agreed that visibility of supply chain management can improve supply chain performance and drive down cost [9] 0 [22]. Yet, most companies still have very rudimentary level of visibility [4]. Surely, practitioners and academics have a general understanding of what SCV is, but it is hard to identify what information needs to be shared and can benefit supply chain partners. Numerous studies measure SCV by the level of information sharing, extent of relationship with supply chain partners, and degree of collaboration efforts [5][7]. However, more recent studies suggest that different supply chain partners require different supply chain visibility [16] [20]. We argue that different supply chain partners require different SCV due to their contextual needs 0, as has also been suggested in the social science field 0. This concurs with *seeing*. The traditional SCV literature, on the other hand, mostly focuses on the *being seen*, as more information sharing can more likely provide context sensitive information.

Internet of Things

Current IoT implementations in supply chains are predominantly dominated by RFID technologies. A recent study showed that there is significant interest by industries to implement RFID, yet only 6% of the respondents have implemented a form of RFID [19]. Various studies illustrated that RFID can bring operational benefits [8] [21] 0 . However, automating may only be a small facet of RFID benefits 0. Delen et al. 0 and Wang et al. 0 demonstrated that sharing RFID data can show even more promising benefits. It is said that by 2020, 50-100 billion things are connected to the Internet 0. IoT enables supply chains to

collect substantial amount of data to monitor operations. However, SCV for the *seeing* is context dependent and finding the needed data in such amount of data can be difficult. We therefore foresee that IoT can indeed help organizations to potentially gain richer SCV and in turn improve supply chain performance. However, it will be even more difficult to construct valuable SCV in the context of the *seeing* from the vast amount of data. We suggest that there is not only a need to define SCV in the supply chain context, but there is also a need to provide guidelines in effectively gaining SCV for industry to follow.

SCV CONCEPTUALIZATION

The proposed view on SCV differs from the traditional literature, as we do not only consider information sharing perspective, the role of *being seen*, but we also consider how the information is used, the role of *seeing*. We call this the SCV duality. The *being seen* is the party, who provides supply chain data and along that line we concur with the literature that more information can result into richer SCV. However, it is the *seeing* party, who actually utilizes the available supply chain data. We posit that the *seeing* role requires context sensitive SCV in order to make more informed decisions. For instance, the diminishing point of sales of a certain product can be alarming for the brand owner, whereas it may only be a mere indication for the production manager to focus on other product lines. Next we verify the SCV duality by discussing the SCV needs in end-to-end garment supply chain.

The ActiveWear Supply Chain

The authors had the opportunity to study a complete garment supply chain, which produces and sells branded garment in Asia. We will call the supply chain ActiveWear, as the supply chain has requested not to disclose its identity.

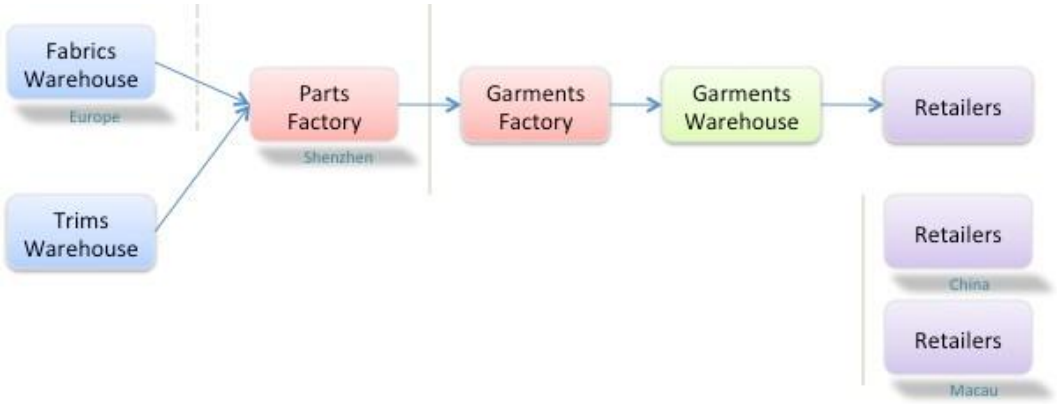

Figure 1. The ActiveWear supply chain configuration

The ActiveWear brand owner operates four different menswear brands and their respective supply chain. Each brand has its own supply chain manager, yet they share most facilities, which include Fabrics Warehouse (FW), Parts Factory (PF), Garments Factory (GF) and Garments Warehouse (GW). Each brand has its own unique retail outlets in Hong Kong, Macau and China. An overall view of the supply chain is shown in Figure 1. For this study, we will only discuss one of the menswear supply chains.

We conducted several rounds of interviews with each individual supply chain partners to find out the visibility needs. Afterwards, we held brainstorm sessions with representatives from all supply chain partners to identify the major concerns of the management. The interviews suggest that information sharing among supply chain partners is not commonly practiced. This forms a stumping block, as a delay at one of the supply chain partners can escalate to other downstream supply chain partners. The lack of information sharing was mainly due to that it is not a common practice and that the information systems were not interoperable. Information sharing is mainly practiced by placing orders with upstream supply chain partners. Although the ActiveWear supply chain partners jointly produce menswear, they operate like independent organizations and are hesitant to share information for the sake of trade secrecy. Obviously, supply chain partners will ask for the production status of their upstream partners, but this is only done periodically. For instance, the garments factory needs to monitor the parts factoryin order to prevent interruptions, but only does this once at the end of each day.

Moreover, we discover issues and concerns of management due to lack of SCV through several brainstorming sessions. The lack of information sharing is causing inefficiencies in the supply chain, yet supply chain partners are unable to identify what supply chain information is needed. The supply chain partners face numerous management problems and these problems require different supply chain information to solve. Besides, not all management problems can be predefined, as ad hoc situations often arise. The brand owner realizes that the lack of SCV made the supply chain inefficient and this is a major concern, as the garment industry needs to efficient and agile in order to set and follow fashion trends.

THE IOT SCV FRAMEWORK: CONCEPTUAL & TECHNOLOGICAL

The ActiveWear case shows that SCV is lacking and very much needed for the supply chain. Discussions between the authors and ActiveWear suggested that IoT, RFID in particular, can be applied to enable SCV. In here we propose an IoT SCV

framework with a two-phase approach, which is suitable for any given supply chain. First, a conceptual framework is developed for a discernable approach to deploy IoT technology across supply chain parties in order to capture supply chain relevant data pertinent to management issues and concerns. A technological second phase is proposed to design an IT platform to deliver context specific visibility to any user of the supply chain on-demand.

A Conceptual On-target Framework

The first phase addresses the *being seen* role to allow more information to be shared across the supply chain. In here we provide a conceptual framework to pinpoint clearly where IoT technology must be deployed given an understanding of current concerns of management. We term the deployment of RFID technology at locations as HotSpots. The framework has three steps as follows:

Step 1 – IDENTIFY. The goal is to critically quantify management issues and identify the possible inefficiency business processes in the supply chain.

- We identified management issues through brainstorm sessions with all senior management of all supply chain partners. We are not looking at problems of a partner, but an overall problem that could be contributing to the performance overall.
- We used SCOR (Supply Chain Operations Reference) model to chart business processes of each supply chain partner. If SCOR is used, Level 3 suffices as level of detail.
- We identified processes with the either incomplete information or missing information. We refer these business process points of interests as Target Points.

Step 2 – PINPOINT. The goal is to deploy IoT technology to capture specific data at operational checkpoints that are designed to enrich the information flow.

- With the SCOR mapping, we further extend the Target Points to Level 4 process element details, with onsite inspection and measurement.
- An IoT data schema is designed which includes the business processes, the supply chain entities involved, e.g., WIPs, and IoT data, e.g., work stations, and production order references.

Step 3 – ACTIVATE. The goal is to deploy HotSpots across all Target Points.

- The underlying IoT data flow infrastructure is designed and tested to ensure a 100% coverage.
- Install the RFID (IoT) equipment at each Target Points – each Target Point is now a HotSpot.
- Activate each HotSpot and test the effectiveness of data capture and flow.

After these steps, new real-time operational data is available for integrative processing. Along with corporate data, the *seeing* can have the opportunity to gain context sensitive visibility. The next artifact offers design guidelines to allow such on-demand visibility be enabled given the on-target framework which builds the operational IoT data map.

A Technological On-demand Framework

The on-demand framework provides steps to deliver context sensitive view of supply chain statuses. This on-demand visibility framework leverages current and emerging ICT to bring operational and managerial staff SCV at any volitional instance. This allows the *seeing* to construct SCV according to their own context at the time of need. The framework has the following three steps:

Step 1 – ONE VIEW. The goal is to present one view of supply chain for all users.

- We use SCOR "language" to present data sources in the context of these business processes.
- Data sources include both corporate and IoT data, but such distinction should only be apparent when a visibility view is presented.

Step 2 – ONE TOOL. The goal is to facilitate all users to share the same experience in creating SCV.

- A self-guided perspective for visibility information is expressed.
- With privacy and security in mind, data sources are only made available based on an access control model, e.g. role-based access control.
- A SCV view can be composed at any time when needed, which is an aspect of on-demand.
- Views can be stored, shared and modified. The construction of a view should be intuitive.

Step 3 – ONE PLATFORM. The goal is to manage visibility delivery centrally with no assumption of technology layer at data sources.

- One contact point for all, independent of the networked device they use.
- One form of presentation of visibility view is enforced.

The proposed framework is to enable users obtain data based on his/her role and location. The presentation of the view is selectable to form the visibility. Furthermore, we do not presume data as they are, but data are dynamically changing and the updated data will be dynamically updated to the users' view. Thus SCV should be on-target and on-demand as suggested by the two-phase framework.

DISCUSSIONS & CONCLUSIONS

Scholars and practitioners in general agree that SCV is beneficial to supply chain performance. Although, we all have a presumption of what SCV is, we often still lack a well-defined understanding of SCV and how it can be applied in practice. Numerous studies associate more data with richer SCV. However, we argue that this is not always the case. We differentiate between the *being seen* and *seeing*. *Being seen* refers to the data owner, who shares information with their partners, which is a prerequisite for realizing SCV. *Seeing* refers to the one interpreting the available SCV, We argue that interpreting SCV is context specific, e.g. a retailer may appreciate point of sales data, but this may only be of little use to a production manager.

Not only did we conceptually explore SCV, but we also proposed on-target and on-demand frameworks to realize SCV. The on-target framework enables data to being shared in IoT-enabled supply chains. This framework allows each *being seen* to share higher fidelity data at each echelon, and as a whole brings clarity data across the supply chain. The on-demand framework allows users, *seeing*, to view SCV according to their own context. We argue that the current literature is still experimenting with how to deploy IoT and how it can automate manual processes. The contribution of this paper lies in how we utilized SCOR to strategically augment transactional data with operational IoT data. Moreover, we introduced an on-demand framework with the intention to make sense use of IoT data and allowing users to shape SCV according to their contextual needs.

Do note that the study only looked into RFID technology to represent IoT and care must be taken when extending it with other IoT technologies, e.g. Bluetooth Low Energy and NFC. However, RFID's characteristics are quite similar to other sensory devices and we therefore do not foresee significant different results with other IoT technologies on a conceptual level. The differences are most likely more noticeable on a technological and implementation level. Although, we used the SCOR model to guide the framework, which allows the framework to be easily adapted to other supply chains.

This study is an initial attempt to further elucidate and articulate SCV. We understand that the quest towards SCV is an iterative process and further research is greatly encouraged. Our experience suggests that further research can be directed in the following areas:

Cloud Computing - It is common that technology adopted at each partner varies. Investing in IoT can be costly and may prevent smaller supply chain partners to adopt. This may leave "blind spots" in the SCV. Therefore, studies are encouraged to investigate in cloud-based approach to further lower the adoption barrier.

IoT & Mobile Technology - RFID technology is proven to be effective to monitor supply chain operations. Yet, RFID benefits often ends at the retail shop, as consumers do not have access to RFID equipment. Future studies could explore other IoT technologies to extend SCV to the consumers, e.g. NFC and QR code of mobile devices.

Big Data - We believe that big data and analytics will add another dimension to SCV. Various studies already investigate how big data affect management decisions. Future studies could explore how big data affects SCV. For instance, social media can gauge consumer sentiment, which can help supply chains to better anticipate on the consumer demand.

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