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Think Exogenous to Excel: Alternative Supply Chain Data to Improve Transparency and Decisions

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Abstract:
Efficient decisions along the supply chain have traditionally demanded sophisticated information sharing processes. Even with decades of research on theoretical and practical developments on integrating systems and stakeholders, in practice, we still seem to struggle to achieve full transparency and mitigate inefficiency challenges. We explore the emerging sentiment analysis technique to augment sales and operations planning (S&OP) with currently unavailable exogenous information. Even though sentiment analysis has gained traction, a comprehensive application in supply chains has not yet been attempted. Relevant topics are reviewed to allow an examination of the key relationships in a process framework, grounded in dual-process and bullwhip effect theory. Our proposed conceptual framework extends our conception of sentiment analysis integration to improve supply chain decisions and performance. The framework addresses managers interested in developing additional analytical capabilities and researchers to initiate further empirical research on the potential held by sentiment analysis in supply chain research.

Keywords: supply chain management, sentiment analysis, bullwhip effect, information sharing, collaboration.

1. Introduction

The increasing importance of supply chain management within broader management practices has enabled firms to focus more closely on customers' expectations and needs. Meeting customers' needs is achieved through improved management of materials, information, and financial flows between firms with the intent of supplying the right product to the right place at the right time in the right quantity and right specification (Mentzer et al., 2001). In addition to the physical movement of materials to markets, the second function of supply chains is the market mediation, ensuring the correct mixture of products makes it to market (Fisher, 1997). Both the transformation-and-transport and market mediation functions require and rely on the transfer and use of various forms of both timely and accurate information, including inventory locations and transport options (physical movement) as well as the understanding of market demand and consumer desires (market mediation). Due to the requirement for information, information sharing and system integration have long been perceived as a fundamental requirement for successful supply chain management (Lee, Padmanabhan, & Wang, 1997).

Contemporary information sharing approaches underpin collaboration and cooperation along the supply chain (Cheng & Wu, 2005; Li, Yan, Wang, & Xia, 2005). A primary method involves the sharing of point-of-sale (POS) data to indicate what is happening in the marketplace. POS data sharing allows information about consumer preference to be shared by other firms in the supply chain and may support decision-making activities. The importance of POS data sharing as an essential element of collaboration over the supply chain has been underscored by many scholars. POS data sharing allows even a firm distant from the market to gauge changes and shifts in preferences and in addition to that, to deliver a superior performance through improved chain coordination (de Treville, Shapiro, & Hameri, 2004; Lee & Whang, 2000; Sahin & Robinson, 2002). Here, we consider supply chain performance in relation to supply chain activities, addressing the end-customer needs and requirements independent of industry-specifics or operational and strategic orientation.

The abovementioned is an expected, traditional, even conservative, and textbook approach to supply chain management. To grasp the need of a paradigm change in order to use exogenous information we have to understand current mechanisms and implications that an upstream supplier has to determine, and evaluate the downstream market demand changes that are often underdeveloped and fraught with problems. Scholars including Stank et al. (2015) and Waller and Fawcett (2013) prognose a shift away from a culture of hoarding information and passing only processed fragments to suppliers towards a culture of improved visibility of (big) data from markets and internal stakeholders as well as towards gaining coordination vertically over the supply chain. While Stank et al. (2015) consider the stronger independence of suppliers and an overall value increase of the supply chain as a major benefit, their suggestions will be challenging to implement as the system still requires humans – that may cheat or make mistakes – and may not always generate outcomes in the best interest of the supply chain. Furthermore, traction for the concepts would require the cumulative development of existing systems and management structures. "Doing more of the same" regarding upgrading systems will, in this paradigm, still struggle to overcome the issues relating to trust between partners and doubts about supply chain transparency.

On the other hand, it is a common issue to believe that one can effectively gain market insight from surveys. However, any survey is resource-intensive, timely, costly to conduct, and will suffer challenges in the sampling control that make many surveys non-representative (Parasuraman, Grewal, & Krishnan, 2006), resulting in often inaccurate market-based demand causing an over- or under-supplying of the market. Costs associated with these excess inventories within the food sector have been estimated as being as high as 12.5-25% or 75-100b of 300b value (Lee, Padmanabhan, & Whang, 2004) and these costs impact on many members of the chain. Furthermore, upstream capacity decisions are made by the perceived strength or long-term success of a given market; therefore, failing to understand the market changes can lead to expensive capacity management mismatches upstream (Chen & Lee, 2012). Indeed, the way in which the costs of mismatches fall disproportionately on upstream members increases the imperative on these firms to prevent errors (Ma, Wang, Che, Huang, & Xu, 2013). Therefore, upstream suppliers using sentiment analysis to receive timely updates to market demand changes can improve their performance.

We take an unbiased look at the market- or demand-driven nature of supply chains with a focus on the generally endogenous information sharing along supply chains. The traditional use of endogenous data is then compared to advancing the use of exogenus data analytics for comprehensive decision-making support. Data analytics on social media data is a growing research area in supply chain management, yet the implications that this has in light of the (theory of) the bullwhip effect are still unexplored. This conceptual research paper proposes a framework to fill this gap by pursuing two major objectives. The first objective is to combine our knowledge of existing supply chain approaches that aim to improve supply chain performance by improved planning and execution, with a focus on the role that 'sentiment analysis' may play in this situation. The second objective is to apply sentiment analysis to develop an integrated process framework to improve supply chain performance. In developing this framework, we draw on the theory of the bullwhip effect (BWE; a.k.a. demand amplification) and 'dual-process theory'.

In this conceptual paper, we identify and explore the emerging phenomenon of sentiment analysis to augment sales and operations planning (S&OP) with exogenous information currently not available along the supply chain. Thus, we first connect sentiment analysis to the concept of demand-sensing in supply chain management. Second, we briefly outline the main techniques of sentiment analysis and how these analytic approaches can be used to gauge changes in the sentiment of product reviews online. Third, we propose a conceptual framework for an effective integration of sentiment analysis to improve supply chain decision and performance. Finally, we discuss limitations and opportunities of the framework for practitioners to develop additional analytical capabilities and for empirical researchers to conduct experiments to validate its effectiveness.

2. The role of demand information in supply chain decisions

Supply chain management has key objectives relating to ensuring the products are in the right locations at the right time and in the right quantity and specification. Accomplishing these objectives requires a level of transparency regarding the activities undertaken amongst members of the supply chain coupled with comprehension about the product characteristics

and quantities that should be delivered to specific markets. Throughout the rest of the discussion we will use the term 'marketplace demand' to denote the actual demand from consumers, the end-users of the product; 'retailer' will mean the firm selling directly to the consumers; and 'supplier' will mean a firm in the supply chain that is manufacturing components, subassemblies, or final products which are yet to be transformed into the finished product or physically shifted to the retailers' premises (i.e., this includes manufacturing and also distributors/wholesalers). The 'tier' reflects the distance of a supplier from the marketplace with *1* being closest and *n* being most distant (see Figure 1).

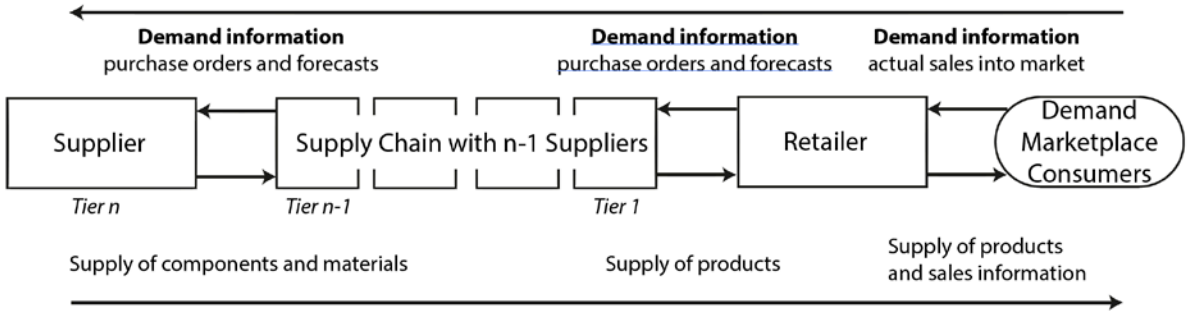

Figure 1. Supply chain showing flow of information and materials/products

The fundamental premise is that more access to better information about the market demand can be used to enhance the decisions made by a single supplier in the chain. In this way, we follow the theory of the bullwhip effect, or demand amplification, where demand order variability increases as orders are passed upstream away from the consumer (Hau L. Lee, Padmanabhan, & Whang, 1997). This theory states that information sharing results in information transmission upstream, with suppliers responding to information that has been distorted by the "repetitive processing of consumption data" (Lee et al., 1997 p. 99). A key method to reduce the BWE is through ensuring that information from downstream is passed upstream quickly (Lee et al., 1997). Despite recognising that technological aspects to facilitate sharing of information upstream have been improved, Croson and Donohue (2006) undertook two controlled experiments to investigate the impact of behavioural causes (decision bias) on demand amplification after providing demand distribution visibility to the participants. They found that the bullwhip effect still existed even after inventory information was available to the participants in real time. These inconsistencies can be explained by incorporating the concept of 'bounded rationality'. For example, while it is generally assumed that supply chain partners are perfectly rational (and, for example, can choose optimal stocking levels that can yield maximum profit), experimental studies have confirmed that human decision-makers fail to optimise inventory as theory suggests (Su, 2008). In addition, Nienhaus et al. (2006) identified 'safe harbour' and 'panic' as strategies that encourage extreme behaviours that contribute to the bullwhip effect. When participants in their study attempted the 'safe harbour' strategy, they ordered more to increase the safety stock levels. When they utilised the 'panic' strategy, they strived to reduce the safety stock levels and then struggled with the increase in end-consumers' demand. Both extreme cases contributed to the bullwhip effect and affected

the supply chain negatively. Therefore, behavioural elements and poor decision-making capabilities can lead to reduction in the effectiveness of decisions (Sterman, 1989).

Based on above discussion, firms' supply chain performance can, therefore, be improved with earlier access to marketplace information. A firm that can better predict demand signals and adjust production or distribution accordingly in a more proactive manner should have an advantage over competitors (Lau, 2012). This 'strategic fit' between the operational decisions and the environmental variables (i.e., marketplace demand changes, in this case) reduces the impact of inefficiencies or costs, such as excess demand, that can accumulate due to the BWE (Stonebraker & Liao, 2006).

Retailers have traditionally had a good understanding of changes in demand, market changes, and shifts in consumer preference. The ability to sell and promote products to the market was often based on this ability to 'sense' what was desired by the market and shape consumer demand accordingly. Successful retailers, who understand and know how to influence the market, often hold a strong bargaining position in supply chains; for example, Wal-Mart's dominance has allowed it to dictate terms, such as requiring the top 100 suppliers to rapidly roll-out radio-frequency identification (RFID) tagging (Fontanella, 2004). More recently, other firms (distant from the market) have increasingly seen the value in the ability to engage in 'demand sensing' activities (Folinas & Rabi, 2012). Awareness of overall demand, which the supply chains seeks to fulfil, should support a strongly demand-driven approach, whereby the supply chain output becomes well-aligned to market requirements. Therefore, demand-sensing solutions should lead to market-focused outcomes with benefits to the firms involved (Folinas & Rabi, 2012)

The challenge, therefore, is to access and use data regarding demand in the marketplace. Most commonly, this is based on the retailer collecting the POS data indicating sales in the market and then transferring this to their suppliers. The use of POS data provides visibility/transparency to both the supplier and retailer whereby benefits may extend beyond the first tier by using other technologies such as RFID and Electronic Data Interchange (EDI). Cross-organisation use of RFID allows firms to manage and track the information relating to the movement and management of stock over multiple tiers and facilities that may be distant to the retailer. However, this requires connections between firms' ERP systems or the use of separate, third-party platforms. Similarly, while POS data sharing can expand visibility over multiple tiers, this is challenging to implement where there is not an existing trading relationship with the end retailer. Also, in both cases, it is more likely that large firms are more amenable to implementing these solutions. With such capabilities, a firm upstream will be capable of sensing shifts in market demand and proactively preparing for these.

Supporting this is the concept of 'visibility' of activities in the supply chain. Visibility has been connected to improved performance and may be enhanced with technology or with specific inter-organisational initiatives (Bartlett, Julien, & Baines, 2007). Identification and recording of stock movements is an essential method to improve intra-firm visibility and has been based on barcoding or RFID technology, where captured item data can be stored in the ERP and used in decision-making.

Inter-firm visibility received a significant boost from the application of several related ICT technologies. First, and perhaps most notably, was the introduction of electronic data interchange (EDI), one of the first technologies that enabled trading partners to transmit data accurately at speed (Attaran & Attaran, 2007). Summarising this research stream, Hazen and Byrd (2012, p. 8) maintain that the technology "promotes enhanced levels of effectiveness, efficiency, and resiliency for the adopting firm". EDI enables the transfer of information so that what happens at another tier can be responded to by the focal firm.

Other management techniques have less reliance in terms of technological solutions. Key methods include just-in-time II (JIT II) (Dixon, 1997); stock replenishment programmes, consignment stocks, and vendor-managed inventory (VMI) (Çetinkaya & Lee, 2000); and collaborative planning forecasting and replenishment (CPFR) (Çetinkaya & Lee, 2000). Each of these enables the upstream partner to undertake a greater role in managing the materials flow to maintain superior service levels (Disney & Towill, 2003), based on improved visibility over a limited scope of the supply chain. Improved visibility leads to better internally focused decisions.

In each of these cases, the emphasis is on a dyadic information sharing arrangement in a way that a particular firm has improved the visibility of supply chain operations. Delays in the transmission of information upstream along the supply chain have previously been identified as a key cause of the BWE (Zhang, 2004). Other factors contributing to the BWE include demand forecast, short lead times, price fluctuations, and promotions (Cachon, Randall, & Schmidt, 2007; H. L. Lee et al., 1997).

In contrast to these often dyadic approaches, sentiment analysis allows an upstream firm to access market-based demand data and can, therefore, be used to improve the upstream firm's supply chain performance. Many of these dyadic approaches ensure earlier access to information about the market or changes that are relevant to the suppliers. The buzz associated with product success and failure can be reflected in social media almost instantly and can be concurrent with actual retail sales. Furthermore, sentiment analysis can also pick up growing interest (or waning interest) in particular products, ahead of actual changes in retail sales. Therefore, it provides early access to data supporting forecasting decisions that will create a positive effect on supply chain performance by enabling proactive changes to be made to capacity and inventory management. Market demand shifts can precede sales shifts, indicating a final delay in information transfer along the chain.

Sentiment analysis is a sub-domain of big data analytics and has become one of the dominant approaches to address the volume, variety, and velocity in social media, that is, qualitative data on platforms like Twitter and Facebook (Waller & Fawcett, 2013). Big data itself became a buzzword in its role as the consequent extension of data warehouses, which primarily operate on structured data. While big data has created new challenges (e.g., data growth, infrastructure, governance/policy, integration, compliance/regulation or visualization), it offers an opportunity for data scientists to develop predictive analytic techniques and discover unknown dependencies across various data sources both within and exogenous to the supply chain (Rozados & Tjahjono, 2014). Common examples are traffic analytics for transport (Khazaei, Zareian, Veleda, & Litoiu, 2016), Internet of Things (O'Leary, 2013), consumer review

analytics and prediction (Chong, Ch'ng, Liu, & Li, 2015), health care (Bates, Saria, Ohno-Machado, Shah, & Escobar, 2014), and social media analysis (Manovich, 2012). As discussed in the following section, sentiment analysis operates using big data, but specifically it addresses the emotions or sentiments in online posts, that is, consumers' feelings expressed within their online reviews. With respect to the scope of this paper, we limit the discussion to the application of sentiment analysis to improve supply chain performance; for a review on algorithm and applications see Medhat et al. (2014).

3. Sentiment Analysis

For a single firm, upstream from the market it serves, there is an opportunity to quickly and directly access data on market-based demand and product acceptance using 'sentiment analysis' or 'opinion mining'. Sentiment analysis is based on textual impressions about products, posted on the Internet. Use of this publicly available data allows a firm to accesses and use consumer-created data to gauge changes in desires and probable spending patterns.

Although information sharing is crucial in supply chain management, there are several significant problems. In this section, we outline these practical difficulties and how this limits the utility of established approaches in terms of information sharing. In particular, we outline the difficulties of some methods of achieving visibility over more than one tier. Second, we outline the behavioural changes required. Third, we provide an overview of how a supply chain change can improve visibility without effective integration.

3.1. Demand sensing with sentiment analysis

What, precisely, can we capture with this approach? First, the pipeline of customers can be inferred and second, we can capture two key pieces of information: the overall impact and the overall sentiment expressed.

Warren (2008) and Finskud (2009) argue that consumers progress through several developmental stages over time, creating a 'pipeline' of customers at various stages of awareness and willingness to buy a product. Supply Chain Managers may be most concerned with the Marketing Managers' evaluation of the overall size and sentiment of the owners and interested consumers categories, and their overall sentiment of the market, as this will indicate future sales and supply problems that the firm may face. Together, these data present a Supply Chain Manager with the opportunity to prepare for changes in the market, in anticipation of future changes in orders from the customers that reflect the market-based changes. Figure 2 depicts the consumer development stages regarding the change of communication about the product. With increasing awareness and interest for a product, the consumer passes through various stages; from not being aware of a product to becoming the owner of it. During these stages, the communication evolves from non-existing to asking a question in support of making a decision towards buying and owning the product.

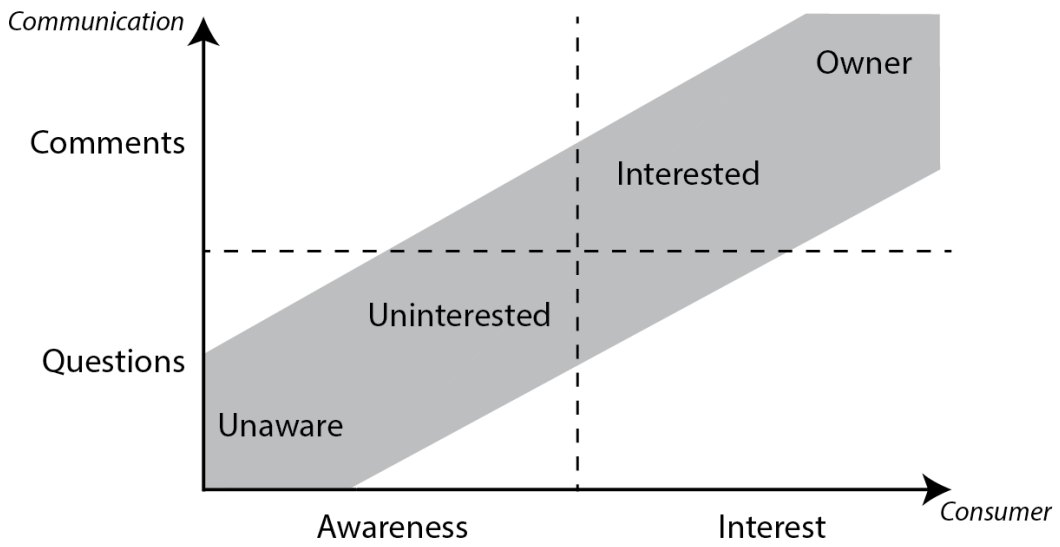

Figure 2. Communication change of consumers in their process of developing an awareness and interest in a product to become an owner but also contribute to the community by reporting on feedback. The figure is based on the Customer Choice Pipeline (Warren, 2008, pp. 345-356).

Capturing the analysis of the corpus of comments and reviews of a product can allow evaluation of the aggregated marketplace opinion and judgement about a given product. A product that is not making much impact in the market is more likely to be cancelled; such a reduced impact early on the release of a product may force Supply Managers to scale back their capacity or ordering commitments that support the production of the item. Overall discussions about particular features may feed into future product development decisions. If a large number of 'interested consumers' are identified, it may be an indication that large sales may be realised shortly. The use of sentiment analysis data can indicate surges/plunges in sales for a product, similarly to how it would be perceived through analysis of the POS data that was captured and shared down the supply chain.

Ultimately, all supply chains serve end-customers or consumers, who act as the source of money for the supply chain. If sentiment analysis is to work, then several relationships must hold (Wood, Reiners, Srivastava, & Duong, 2014). First, consumers must in practice discuss products and provide opinions online as this provides the data that must be captured. Second, these expressed opinions must correlate with sales of that product to consumers. Third, the opinions must be amenable to automatic processing with judgements made at the conclusion.

3.2. Consumers evaluate products

If products excite or disappoint consumers, we would anticipate that the consumers will express their feelings about the product. Where the opinion is written, online in an open forum, then the raw data is available to support the sentiment analysis approach.

Consumer opinions expressed online are most likely to occur in the business-to-consumer (B2C) market where the users of the product are happy to share and comment on their products or others' products. Consumer reviews are a foundation for the success of social media and Web 2.0 technologies (e.g., powering Facebook); in particular, Gen X and Y love to share, particularly with those close to them in their network (Jansen, Sobel, & Cook, 2010). In

contrast, this is unlikely to be useful in business-to-business (B2B) markets or with B2B products; this is an inherent limitation of the approach.

Within B2C markets, there is a heterogeneity of opinions expressed, with particular product categories being more commonly commented on than others. When a product is relatively expensive, consumers are likely to do more on-line research and discussion on the product before they make a decision to purchase, for example, a large TV or a computer system. Alternatively, consumers may respond to a mundane product that has experienced change, for example, a food product with a modified recipe that is perceived as being less palatable. This occurred when Cadbury's substituted palm oil for traditionally used cocoa butter in their chocolate (Adams, 2012).

3.3. Discussions can be used to predict retail sales

If consumer discussions are uncorrelated with actual sales, it would be pointless to use sentiment analysis to gauge market demand. However, a growing body of research has empirically validated that posts, discussions, and comments created by users on social media sites can be used to predict behaviours of individuals (Goel & Goldstein, 2013) where such behaviour may include purchasing decisions.

Empirical evidence also shows that sentiment analysis tools may predict sales volumes. Therefore, they can be used to create a connection between the release of a product, the overall online discussion, and then the actual sales of the products. The overall volumes of discussion can be used to predict or estimate sales volumes (Baek, Ahn, & Oh, 2014; Duan & Liao, 2013; Wang, Cai, & Huang, 2010). Even the number of fans on Facebook can be correlated with retail sales (Schultz, 2016). Other researchers note that it is not just the overall volume but also who the messages are coming from (Lică & Tuță, 2011). In this way, "online [word of mouth] and expert reviews play a critical role in moviegoers' consumption behavior in the age of the Internet and social media" (Kim, Park, & Park, 2013, p. 98).

While much of the earlier research has focused on predicting sales of box office movie releases, the same results hold true in other industries. When studying hotel revenue, Blal and Sturman (2014, p. 373) note that the "use of [electronic word-of-mouth] data from one time period to predict [sales performance] in a subsequent time period provides strong support for the conclusion that [electronic word-of-mouth] indeed has organizational-level effects". The use of online product reviews can also improve forecasting accuracy of entertainment goods (Dellarocas, Zhang, & Awad, 2007).

In many cases, the value of the sentiment information in reviews lies in supplementing other forms of analysis, such as with past sales performance (Yu, Liu, Huang, & An, 2012). Predictions of box-office revenue can be improved by also using an online prediction game and an online prediction market (McKenzie, 2013). The use of more data often provides greater accuracy in forecasts, particularly when using behavioural data from social network services (SNS) (Kim, Hong, & Kang, 2015). The use of such 'secondary search data' can enable firms to predict sales better (Chandukala, Dotson, Liu, & Conrady, 2014).

Qin (2011) clearly demonstrated the ability to predict sales in the marketplace, based on consumer comments on publicly accessible social media. This predictive ability is important as anyone – including upstream suppliers – can access these data (i.e., the consumer comments), analyse them, and draw the same conclusions. These data are available in real-time and are simultaneously and equally available to all members of the supply chain. Where the product in question is a 'feature-based' product (e.g., consumer electronics such as a smart phone), review content will often provide an evaluation of objective features or functions. Particularly, feature reviews may be valuable when the overall utility of the product is essential (Cheema & Papatla, 2010). However, 'experience goods' often balance objective evaluation with a subjective opinion about the experience (Ghose & Ipeirotis, 2006); here, the classification and connection may be more closely connected to "buzz" about something rather than objective analysis of it. This nascent area of research requires closer examination of the moderating role of product category on the nature of reviews and the resulting value of the reviews within the sentiment analysis process (Maeyer, 2012).

With this empirical validation of the concept, we can assert that the social media postings may be analysed in terms of product sales for a particular product.

3.4. Automatic analysis and processing of the data must result in summarised information useful for Supply Chain Managers

Practically, a manager does not have hours to pore over social media postings nor the ability to make a gut judgement based on these. Therefore, the data must be able to be analysed and summarised automatically so that useful information can be included in decision-making activities. This automatic analysis and summarisation is called 'sentiment analysis' or 'opinion mining'.

Most conventional natural language processing (NLP) analyses are based on a combination of machine learning or 'training approaches' (Prabowo & Thelwall, 2009). In all cases, it is necessary to understand both words and the concepts behind the words, and how these are connected to create a useful 'parcel' of information. (Cambria and White [2014] provide an extensive overview of NLP research.)

Just capturing the meaning of the item of text is inadequate – further details must be extracted so that the data can be aggregated and analysed to provide useful insight. Chen and Zimbra (2010) note that a 'direct opinion' is a quintuple of five parts of information: the object, a feature, the orientation of opinion, the opinion holder, and time expressed. Together, these data enable us to capture what is being said or opined about the product and determine the strength and direction of that sentiment. In particular, details must be identified about the object/product being discussed. In many situations, it may be expedient to classify opinions as 'positive', 'negative', or 'neutral/no opinion', adopting the product classification approach outlined by Pang and Lee (2008).

When all items have been classified, it is possible to evaluate the total sum of each category to capture, at a glance, whether the overall opinions are positive or negative. As the overall stocks change dynamically, these can be obtained and analysed to provide an "early warning system" or a "canary in the mines" to feed into proactive decision-making systems.

Furthermore, the change in trend or direction of sentiment can be detected and determined with automatic processing/algorithms (Kim & Kim, 2014).

4. Theoretical framework and propositions

A framework for the incorporation of sentiment analysis into firms' decision-making to improve supply chain performance is proposed (Figure 3). Also, support from the theory of the BWE and strategic fit is provided for stronger theoretical support where appropriate.

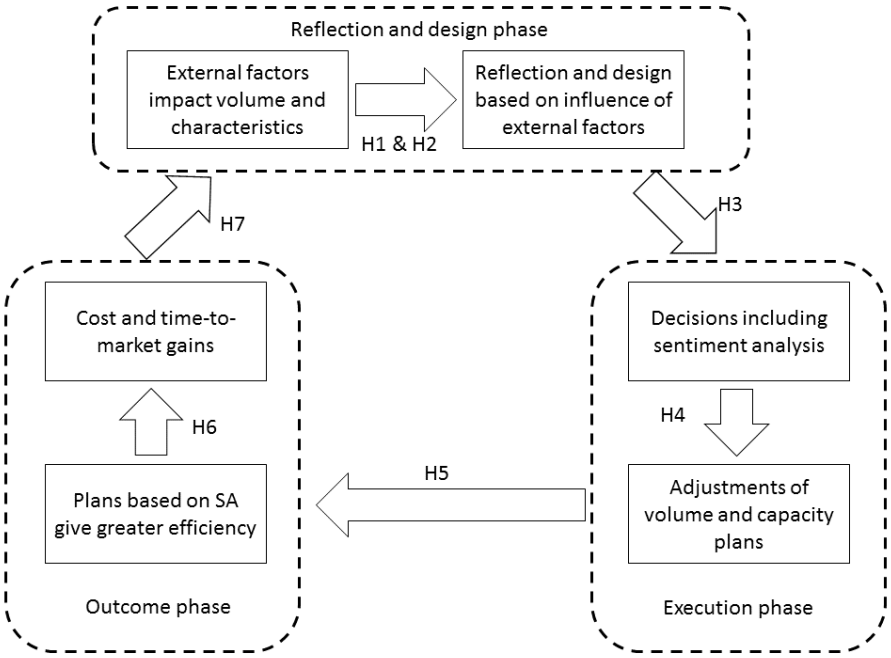

Figure 3. The Sentiment-Analysis driven supply chain process framework

4.1 Reflection and design phase

As highlighted by Dooley et al. (2010), having information does not ensure that it is used; managerially focused research must support decision-makers using the information provided through IS. Such an incorporation of multiple sources of data is not necessarily achieved instantly; the problem is not simply to provide data but also to ensure effective integration into decision-making processes, indicating the importance of psychological principles. Therefore, the first phase is based on *dual-process theory*, which assumes that autonomous or intuitive mental processing takes place unless there is intervention involving a higher-order reasoning process (Barr, Pennycook, Stolz, & Fugelsang, 2015; Evans & Stanovich, 2013).

Frederick (2005, p. 35) proposes that an individual's *cognitive reflection* is the "ability or disposition to resist reporting the response that first comes to mind". In our context, it refers to a manager using the best sources or making a carefully weighed judgement, rather than only relying on the most pressing source of information. A fast or autonomous judgement about information would lead managers to rely on existing forecasts less critically; this represents a Type 1 process (Evans & Stanovich, 2013). In the case reported by Dooley et al. (2010), weak

cognitive reflection might lead to managers basing their decisions only on the retailer orders, rather than also making use of the retailer demand data. Individuals with a developed cognitive reflection would be more able to assess the complete range of information sources – including those derived from the sentiment analysis approach we have outlined – and build these into a more comprehensive set of supply chain plans for the organisation. This 'cognitive reflection' on the data may be a valuable skill for many managers. We might infer that as we saw in Dooley et al. (2010), the managers, concerned with the more immediately pressing KPIs relating to their immediate downstream customers, rather than the overall health of the supply chain, might be those with lower levels of cognitive reflection. Rather, managers need to be concerned with the environmental changes and take the time to incorporate these factors in decisions, if they wish optimal outcomes (Leaptrott & McDonald, 2015).

Managers possessing high cognitive reflection should be able to integrate a range of data. This is alluded to by Dooley et al. (2010, p. 17) when they note that firms "must balance local and global information, and the recent emphasis on integrated supply chains, which tends to focus on immediate upstream and downstream coupling, may have led to a decision environment where 'external' news was relatively ignored". These external and in many cases more ambiguous factors will have greater influence if managers have higher levels of cognitive reflection and the ability and willing to engage in Type 2 processes (Barr et al., 2015). Type 2 processes are higher-order, careful, and reasoned judgements that incorporate these exogenous factors into the decision-making processes. Sentiment analysis may not provide exact or precisely quantifiable movement or shifts of demand that other approaches might. Rather, sentiment analysis would be one of a range of input information into supply chain decisions. Therefore, sentiment analysis can provide early access to insight into market-based demand data but will only deliver value when managers carefully use this. Therefore, managers with higher levels of cognitive reflection are better-positioned to use sentiment analysis in supply chain decisions. We therefore assert that managers possessing higher levels of cognitive reflection will be more successful in combining a range of data and, therefore:

> *H1: Exogenous factors will have more influence on decisions in users with high levels of cognitive reflection.*

"[I]ndividuals high in need for cognition are thought to be more likely to expend effort on information acquisition, reasoning, and problem solving to cope with a wide variety of predicaments in their world" (Cacioppo, Petty, Feinstein, & Jarvis, 1996, p. 199).

Almost axiomatically, having last-minute access to information requires the use of existing decision-making frameworks. A lack of time removes the opportunity to reflect, resulting in managers' 'expediting' decisions with short timeframes (Leaptrott & McDonald, 2008). Therefore:

> *H2: Early access to information from exogenous factors will have more influence on decisions in users with high levels of cognitive reflection.*

The premise that effective design leads to improved execution has been examined in operational contexts: careful design of product-process design to improve new-product development (NPD) processes (Lu & Wood, 2006); effective design of customer-experience systems to promote loyalty (Fawcett, Fawcett, Cooper, & Daynes, 2014); or the use of sales and operations planning (S&OP) as a 'decision-making forum' for both tactical and strategic decisions (Stank, Dittmann, & Autry, 2011).

Therefore, it is proposed that:

H3: The reflection and design phase will lead to the execution phase

4.2 Execution and decisions

Following the reflection and design of mechanisms to include and use sentiment analysis, the planning and execution phase will take place. Based on the theory of the BWE, we know that having earlier access to marketplace information enables firms to analyse and compare actual order information with demand signals obtained from sentiment analysis. This helps firms to counteract behavioural causes of the BWE and support them to develop and execute plans to better position themselves for changes in the marketplace. The additional information from sentiment analysis contributes to firms' "need to coordinate activities, integrate operations, and balance supply/demand across supply chain members" (Thomas, Defee, Randall, & Williams, 2011, p. 664), as influenced internally by the S&OP process.

Amongst the sectors examined by Dooley et al. (2010), the automotive supply chains stood alone insofar as upstream firms in this sector did not experience an increased volatility of demand or orders being placed. These automotive supply chains are more likely to be shorter than other supply chains (note that the use of aggregated data by Dooley et al. [2010] limits our ability to specify this). However, the lack of forecasting and resulting demand-supply mismatches are an area of concern in agri-fresh produce supply chains (Shukla & Jharkharia, 2013), which are also often short chains.

In traditional S&OP processes, the effort to balance supply and demand may rely on shared forecasts from customers or forward orders. Complex environments benefit from the use of more information in the analysis (e.g., through APS) to support S&OP (Kjellsdotter Ivert & Jonsson, 2014). In the future, incorporation of sentiment analysis might enable the 'demand-side' meetings to consider the use of sentiment analysis to derive marketplace changes where this factor would be an influence in the decision-making process. "The S&OP process is part of the operational and line management processes. It is through this process that the operational alignment to strategy can be managed and implemented" (Godsell, Birtwistle, & Hoek, 2010, p. 14). By including sentiment analysis as an augmentation of the standardised S&OP process, the execution phases can be enhanced, by improving some of the underlying behavioural comprehension of time delays, feedback, and other behavioural challenges to effective supply management.

While sentiment analysis holds the promise of quickly and effectively allowing an assessment of market-based demand, we certainly do not claim that this is, by itself, a "silver-

bullet" or a panacea to some of the difficulties that we have outlined. Rather, we envisage the value from our proposed approach as an early warning system and a source of information that is not necessarily correlated with other (existing) sources; it acts as a support to counteract behavioural issues that relate to poor decision-making. This alternate perspective may be important as it can show a divergence in what is occurring in the environment, and is able to give pause for thought to managers possessing high levels of cognitive reflection. Mature and effective S&OP processes and leadership of these processes enable effective S&OP integration and effectiveness (Grimson & Pyke, 2007), indicating a high level of initial involvement. Sentiment analysis would, therefore, be a single influence and source of data amongst several others.

Sentiment analysis can inform decisions taken ahead of time. When information is received earlier, it can feed into the S&OP process, enabling a better balance or matching between the ability for the firm to produce or supply the product in the future vs. what the anticipated demand will be. These processes include an analysis of required supply, consisting of production or inventory volume and capacity, to meet the anticipated demand. Understanding demand earlier will enable further changes to supply-side decisions (e.g., more time to develop a larger inventory stock in anticipation of an increase in orders coming through the supply chain). "A well-supported sales and operations planning and rough-cut planning of production quantities ensures production at the lowest [total cost of ownership], with respect to manufacturing productivity, material and logistic costs" (Fuchs & Otto, 2015, p. 88). Therefore, the earlier inclusion of sentiment analysis in the analysis enables more adjustment to lower these costs.

Where there are significant changes in market requirements, the higher market volatility and uncertainty would suggest that early access to data regarding what is happening in the market will be most valuable. Managers require an appropriate infrastructure with integrated systems and technologies to benefit from the information and react accordingly.

From these discussions, it becomes clear that firms have recognised the importance of market changes for decision-making. Management techniques and technology solutions enable faster oversight of market changes, remove the 'barrier' that firms between the focal firm and the market represent, and effectively position the firm so it is 'chronologically closer' to what is occurring in the market. At the foundation of this effort is the awareness that knowing market changes early on enables firms to make better decisions and undertake better-planned actions. Earlier access to this market-demand data will have a greater impact on operational plans involving production or inventory volume and capacity.

Therefore, we propose:

H4: Early access to data using sentiment analysis will have a greater impact on adjustments of operational plans involving volumes and capacity

The use of market-based data is important, as it allows firms to avoid the information distortion commonly associated with the BWE (Chen & Lee, 2012). Improved access to market-based data is most useful where it is incorporated into efficient decision-making.

Following the Global Financial Crisis (GFC) from 2007 to 2009, Dooley et al. (2010) examined the amplification of demand and transference of order variability over supply chains during this tumultuous period. The research was based in the US and encompassed retailers, wholesalers, and manufacturers. We can infer that these were (relative to the rest of the world) well-resourced firms, acting in one of the largest and most sophisticated markets in the world. If there were management techniques or technologies that could improve supply chain management, these are the firms that should have been employing them. As a result, we would have expected these firms to have managed successfully throughout the Global Finance Crisis and that this should have been reflected in their management in the face of changes in market demand and order variability. However, despite their significant advantages, Dooley et al. (2010, pp. 16-17; emphasis added) noted that "[w]holesalers may have been paying too much attention to retailer demand, and not enough attention to consumer demand, *even though such data was readily available to them*". This insight indicates that the proximity to the end consumer *should* have allowed the firms to understand the shift in demand and then respond to it, in near-real-time – but they failed to do so; instead, behavioural problems contributed to poor decision-making.

As expected, the classical outcome occurred whereby the BWE most impacted firms furthest from the market. Dooley et al. (2010, p. 15) noted that "[b]ecause of [the wholesalers'] farther distance from the consumer, they were slower to react, and this led to the need for them to take more drastic action". During the recession, market demand and retail sales shifted, significantly increasing the standard deviation of orders upstream. The uncertainty, exacerbated by the BWE, affected firms distant from the market who were not attending to market-based data.

Alignment of activities and processes over the supply chain often occurs to reduce the impact on the BWE on suppliers. When these projects take place, there is "improved alignment [as the] supply base becomes more agile and able to respond rapidly to customer requirements due to improved understanding of these requirements" (Handfield, Cousins, Lawson, & Petersen, 2015, pp. 13-14). Particular technology-driven planning improvements, such as the use of ERP, often lead to improved supply management (Huang & Handfield, 2015, p. 16). However, a range of planning and execution activities may be required as combinations of activities often create synergistic benefits to the firm (Handfield et al., 2015). Synergistic benefits can accrue particularly where the challenges in improving planning processes come not from technical elements but behavioural causes of poor information sharing and use, driven by individuals in the system (Wallace & Stahl, 2006). Therefore, the ability to plan and execute based on market-demand, rather than the market demand itself, can generate positive supply chain outcomes.

Early understanding of changes in the market enables a firm to plan their supply management activities more appropriately. Effective supply management planning supports positive financial and operational outcomes for firms. Therefore, we present the following hypothesis:

> *H5: Executed plans based on sentiment analysis will have an influence on supply chain outcomes.*

4.3 Supply chain outcomes

Supply chain outcomes can be improved by counteracting the BWE. Therefore, early access to and effective use of information can allow operational decisions to be made that minimise costs of the firm and position them to respond more quickly to market changes.

Implicit in the theory of the BWE is that the amplification of demand, and the poor outcomes that many actors create, reduce their ability to respond appropriately. This is important as "[d]emand response is the ability to anticipate or handle changes in marketplace demand" (Ralston, Blackhurst, Cantor, & Crum, 2015, p. 48) and firms' demand response and integration within the firm has an impact on cycle time process performance and financial performance (Ralston et al., 2015).

A firm can become increasingly distant from the market that their output eventually serves, by the increasing levels of outsourcing along the chain. Where suppliers are further upstream (i.e., there are many tiers between themselves and the marketplace of final consumers), access to marketplace demand data becomes more useful, and performance improves. In shorter supply chains, manufacturers can evaluate market demand changes; for example, a food manufacturer often occupies a short chain and is often domestic, providing closer access to market data and managers will have some awareness of market requirements. "[S]upply chain performance depends on effectively integrating supply and demand" (Thomas et al., 2011, p. 662) as the integration allows the firm to create an appropriate demand response. The further the firm is from the market, the more time the firm will have to create an appropriate response.

Long chains are also logically correlated with slower information transfer along the chain. Therefore, a lengthy chain where the focal firm is far upstream from the market will present the opportunity for a supplier to benefit more from early access to market-focused data. The supplier can then position themselves, compete for scarce suppliers or customers, and organise their production and inventory schedules ahead of time to prepare better for the coming increase/decrease in consumer orders. Earlier access to information means more time to make effective planning decisions and execute optimally. Improved planning should lead to lower inventories to meet required fill rates (providing cost benefits) and also enable the firm to more quickly meet customer orders (improving time-to-market). Such an impact can be seen, albeit over few echelons and based on forecasts rather than market demand, where order variability decreases (Lu, Tsai, Chen, & Lee, 2013). Reduction in order variability is a common result, where customer information from several downstream echelons can be used to improve the supply chain performance at a given firm (Kumar, Mukherjee, & Kumar, 2013)

Understanding changes in markets may be easily achieved with short, transparent, and tightly integrated supply chains (e.g., a virtually vertically integrated supply chain). However, most managers do not have the luxury of selecting the attributes that they want; instead, they face these attributes as a given in their particular type of supply chain facing exogenous variables and are therefore constrained and unable to change these attributes. The possibility remains for a firm to look downstream, towards the marketplace, and use sentiment analysis to gauge whether consumer demand is changing.

Firms distant from the final consumers of their product will benefit more from understanding the changes in marketplace demand. Sentiment analysis can provide them with a better understanding of significant changes, and it can do this in real-time, faster than they could gain similar insight through collaborative or information-sharing approaches along the supply chain. The general principle should apply, that the further upstream a firm is, the more valuable the market demand data is, and therefore we hypothesise that:

> *H6: Execution based on sentiment analysis data will have a stronger effect on supply chain performance where the focal firm is distant from the market.*

Improved supply chain performance provides a greater likelihood for greater use of data on external influences. First, firms already capture manufacturing planning data (e.g., product breakdown and relationships in BOM files, and inventory levels) that are internal. Second, firms already engage in forecasting processes and are able to make the appropriate connections between the outcome of the internal proccesses into other decision-making processes (e.g., through the use of S&OP). Therefore, a method is needed to integrate changes in sentiment analysis outcomes with existing forecasts. Firms that have seen and evaluated benefits from a limited pilot will be more willing to invest further resources in developing these capabilities further. This method, of combining the insights with traditional/existing forecasting, is a task we leave to future researchers, but we have presented a model to demonstrate where the analytical results 'fit' into the existing information systems architecture. This type of success in a method often sees a further uptake in the future, for example, as observed in the use of QSAM methodology by Atilgan and McCullen (2011). Such models often focus on an iterative cycle of improvement and support effective executions with a focus on continual improvements. Therefore, we propose:

> *H7: Improved supply chain outcomes improves ability to access exogenous factors and use these in decision-making.*

5. Theoretical and managerial implications and limitations

In this exploratory and conceptual paper, we have highlighted the existing difficulties and challenges associated with accessing market-place (i.e., consumer demand) information when a given firm is upstream from the market. Incorporating the market-place information into decisions should lead to improved supply chain performance. The improved performance comes from the way that sentiment analysis can be used to counteract behavioural elements contributing to the BWE. A framework is presented based on literature and the dual-process theory and theory of the BWE; however, this framework has not been empirically validated yet. Thus, while our propositions are theoretically grounded and are conceptually appealing, they can probably be further refined through analysis of the phenomena in practice. Given the acceptance of the underlying frameworks, several theoretical and managerial implications can be inferred.

What has to change to counteract the BWE effectively? Information is crucial and, therefore, access to direct market data is a logical addition to information passed upstream, that is, as a supplement to orders from customers. The use of sentiment analysis – as an alternative and emerging approach to gain direct insight on marketplaces – has been introduced in this paper as a technology. However, we note that this method is not a silver bullet and suffers weaknesses in the practical application. Sentiment analysis should, therefore, only be used as part of a wider portfolio of approaches when making supply chain decisions as it can contribute to reducing behavioural impediments to effective decision-making but may not be valuable for precise forecasts in the execution phases of supply management.

By positioning sentiment analysis as a tool with latent value to supply chain managers, we hope to provoke greater interest in these emerging analytic approaches and how they can be incorporated into existing analysis methods.

Even though firms have undertaken considerable work to improve IT investments and dyadic information flow, there is still evidence that existing approaches to combatting the BWE are not entirely effective. First, they do not include recognition of dual-process theory and the difficulty in incorporating and using information, particularly that which is longer-term and less reliable. From our first phase, we can see that if there are difficulties incorporating this information, it will have little impact on downstream processes (i.e., those downstream in the decision-making process). Second, existing dyadic information-sharing processes do not explicitly require inclusion in existing planning and execution processes. Our model addresses this through connecting with the commonly used S&OP processes and reducing behavioural challenges to improved supply management. Third, we focus on a continual improvement cycle, where benefits from one cycle should lead to greater examination and use of exogenous factors to further improve planning, rather than one-off processes. This dynamic improvement cycle requires sustained attention and effort.

Even though the proposed framework consists of a series of qualitative propositions that are refutable, there is still the challenge to conduct an in-depth case study to test or further refine the propositions. This case study would uncover elements that firms are using to improve or aid the use of sentiment analysis in their supply chain decision-making processes, and these elements may be used to enhance the model.

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