Assessing the Value of Supply Chain Information Sharing in the New Millennium

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***Abstract* – Information sharing in supply chain management has been studied extensively during the past several years. Many scholars agree that shared information will lead to significant cost savings through inventory and batch size reductions, productivity gains, and other measurable. The purpose of this paper is to review the information sharing related studies in supply chain management research, identify core issues, and offer suggestions for future research. Fifty-five articles were collected from the premier refereed journals in the fields of Supply Chain Management and Operations Management. The findings of this study indicate that information sharing in supply chain management is still an evolving field. Classification of the articles based on four common information sharing themes is presented in the paper. A majority of the articles included in this review concentrate on an element of information sharing that leads to strategic changes at the manufacturers and suppliers as well as the type of information shared (demand, inventory, production) and the mechanism utilized for information exchange. Potential future research ideas include additional empirical work and investigation into the "leakage effect".**

***Keywords* –** Information Sharing, Supply Chain Management, Value, Collaboration, Exchange, Literature Review

1. Introduction

Supply Chain Management (SCM) is the evolutionary product of the traditional purchasing, operations, and logistics functions in an organization. A supply chain consists of a network of entities that typically includes manufacturers, distributors, wholesalers, and retailers. Supply Chain Management is designed to create a linkage between the external operations of the various suppliers in the supply chain, the customers, and a firm's internal functions [1]. The ultimate goal of this supply chain integration is increased operational performance and to establish a potential competitive advantage for the firm and overall supply chain.

One of the most widely used definitions of Supply Chain Management comes from the Global Supply Chain Forum:

> Supply Chain Management is the integration of key business processes from end user through original supplier that provides products, services, and information that add value for customers and other stakeholders (Global Supply Chain Forum as reported in [2], p. 1)

Supply chain management investment by organizations has exploded over the past several years as well. This increased focus on SCM investment suggests that companies see SCM as a key component to sustainable business relationships and an avenue towards enhancement of company performance.

Information technology (IT) has made a major impact on the nature and structure of supply chain management. Information technology can be considered as the core of a successful supply chain due to the ability of the various forms of IT to: improve communication, enable effective decision making, acquire and transmit data, and enhance performance of the supply chain [3]. There are a wide variety of IT applications that are used in many manufacturing and service organizations throughout the world. Examples include scanners that collect inventory and point-of-sale data and radio frequency identification technology that can track data on a product from the beginning of its life cycle until the end when the product no longer has value.

Ref. [4] studied the effects of information technology on supply chain performance in the setting of Campbell Soup's continuous replenishment program. The continuous replenishment program is designed to improve the efficiency of inventory management with the following three techniques: "1) retailers pay a constant wholesale price but continue to participate in consumer promotions, 2) retailers transmit to the supplier daily inventory information via electronic data interchange (EDI), and 3) the supplier assumes responsibility for managing retailer inventories." The results of the study illustrate the benefits of IT implementation due to the 66% average reduction in the retailer's inventory and a 1.2% reduction in the retailer's cost of goods sold, which according to the authors, is a significant change because the grocery industry traditionally has a low profit margin. Ref. [5] also studied the impact of information technology on supply chain performance. They conclude that business process reengineering via channel transformation

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enabled by EDI will lead to 50-100% higher inventory turns for products on continuous replenishment processes in the retail grocery market.

As the above examples indicate, information technology facilitates information sharing and collaboration along the supply chain, which can lead to cost savings through improved production planning, inventory reduction, and decreased order variations (Bullwhip Effect). The Internet and Electronic Data Interchange are the two primary vehicles that drive electronic transactions and information exchange in supply chains. The Internet and EDI facilitate real time data exchange among the participants in the supply chain. This real time data can lead to tremendous cost savings and gains in efficiency. The increased profit that is provided to companies from the cost savings and efficiency improvements is the primary motivator behind information technology implementation in the supply chain.

Information sharing is one benefit of using information technology that can make the largest impact on supply chain performance. Ref. [6] conducted a series of tests to determine the effects of real-time data and information sharing. The objective of the experiment was to measure the value of information sharing and compare it to other methods of supply chain performance improvement. The question that they attempted to answer is: "does the primary gain (supply chain performance) come from sharing information or from allowing products to flow more quickly and evenly in the supply chain?" Even though the authors determined that it is more valuable to implement information technology to accelerate the flow of goods than utilizing IT to facilitate information flow in the setting of their study, they contend that real-time information sharing will also lead to improved supply chain performance from reduced inventory at the supplier level based on an improved ability to predict or detect demand changes.

A primary benefit of information sharing that is often studied in the literature is the effect of information sharing on the "Bullwhip Effect" (BWE). Similar to the motion of a cowboy cracking his whip, the BWE is the increase in order variance (amplification) up the supply chain, as demand information passes through the supply chain and is misused/misunderstood by the suppliers [7]. Proctor & Gamble characterized this phenomena as the "Bullwhip Effect" based on the ordering pattern that was observed from retailers and suppliers of Pampers Diapers [7], but the original discovery of the BWE dates back to research conducted by ref. [8], [9]. The inefficiencies created by the BWE result in severe cost implications for the supply chain members due to excess raw material cost, additional manufacturing expenses (excess capacity, overtime, etc.), excess warehousing expenses, and additional transportation costs [7]. Therefore, elimination of the BWE has been passionately pursued by both practitioners and researchers. Real-time demand information sharing is one approach to reduction and minimization of the Bullwhip Effect [10], [11], [12], [13].

The past several years have brought forth an abundant amount of research on the value of information sharing in supply chain management. Information transfer between companies, suppliers, and customers has opened the door to tremendous opportunities for improvement in supply chain performance. A variety of topics have been studied including the value and/or benefits of information sharing, the technology that supports information sharing, the quality of the shared information, and the content of the information, just to name a few. Despite the flurry of activity, one thing this rich field of research lacks is a comprehensive framework to link all of the prior research and to serve as a guide for additional research. The objective of this research is to offer an information sharing classification framework based on a consolidation of literature pertaining to the aforementioned topics and to pinpoint issues that require further research. The intent of this research is not to conduct an exhaustive review of the literature. Instead, we intend to highlight some of the key and recurring themes that appear throughout the articles selected for review. A literature review will be beneficial to both practitioners and researchers from the standpoint that it will describe the current research frontiers, highlight thoughts and ideas to consider for information integration, and provide a roadmap for future research.

The remainder of this paper is constructed as follows. Section 2 provides a description of the research method and article collection process, including the targeted journals. Section 3 examines the information sharing in supply chain management research trends and classifies the research based on the common themes of information sharing retrieved from the literature. Section 4 identifies the fertile ground and avenues for further research. Finally, the paper concludes with limitations to the study and a summary of the key findings.

2. Literature Review

There are a few authors that offer a taxonomy or framework to summarize the information sharing in supply chain management research. All of the prior literature reviews are comprehensive in nature, however, they tend to focus on the information sharing literature as it pertains to one element of operations/supply chain management such as flow coordination [14] or supply chain dynamics [15]. Some of the articles are included as part of this research, while the other articles that review the information sharing literature surfaced during the article collection process but are not explicitly contained within the fifty-five articles presented here. The goal of this research is to combine some of the elements from prior literature to create a broad yet comprehensive information sharing framework.

According to ref. [14], information sharing occurs at different levels and/or in different amounts. They characterize the extent of information sharing as a continuum from "no information sharing" to "full information sharing" with varying degrees of partial information sharing in between. Ref. [16] discusses information sharing in the context of supply chain coordination as part of an overall review of manuscripts published in *Production and Operations Management*. Ref. [15] categorizes the information sharing literature based on the sharing mode and the type of information shared. According to ref. [16], the mode of information

sharing can be summarized in two dimensions: neighborhood and timeliness, where the "neighborhood" of information sharing refers to recipient of the information or whom the information is shared with, and "timeliness" refers to shared information arriving early or late. Another category of information sharing offered by ref. [16] is the type of information shared, which can come in the form of inventory, order, planning, and resource information. Finally, the authors identify some costs associated with information sharing (installation of an information system and acquisition of information) and call for additional research on the cost of information sharing and incentives that might motivate the supply chain partners to share information.

Ref. [17] provides a taxonomy of information sharing research that centers on three dimensions: information sharing support technology, information content, and information quality. Information sharing support technology covers the IT application and hardware involved in the information sharing process. Information content is a broad dimension that is defined as the information that pertains to the supply chain members (manufacturers, suppliers, customers), whereas information quality concentrates on the degree to which the information meets the organizational intent of the information exchange.

Information Sharing in Supply Chain Management research is diverse in nature due to the fact that many different scenarios are explored and the research methods range from complex mathematical models to empirical work to qualitative research and case studies. Despite the various angles of information sharing highlighted in the articles above, there is one similarity shared by all of the papers, which is the positive organizational impact and potential outcomes of shared information on all supply chain members. The framework presented in Figure 1 is designed to frame the classification scheme of information sharing in supply chain management research by integrating the elements detailed in prior information sharing frameworks and taxonomies, in addition to recurring themes that emerged from this review, to unify the stream of research and to serve as a guide for future research. In many organizations, information sharing begins by establishing the motivation to share information, which may be driven by the internal or external environment (suppliers, customers). Next, the information is shared with other members of the supply chain. The synthesis of information sharing research uncovered four categories or themes of information sharing in supply chain management, which include information sharing quality, information sharing mechanisms, information sharing investment, and information sharing type/value. Each category will be described in further detail in the coming sections. The scope of information exchanged is the next element of the framework presented in figure 1. Some information is exchanged with relatively few member of the supply chain, whereas other information may be exchanged with all members of the supply chain. Finally, many articles hint at the organizational impact and the value created for the organization (cost reduction, improved competitiveness, increased customer satisfaction) generated by sharing information throughout the supply chain.

The "Information Sharing" portion of the framework in figure 1 will serve as the foundation for the classification scheme that follows. With that in mind, every effort was made to effectively classify the articles in the manner that is most appropriate based on interpreting the literature.

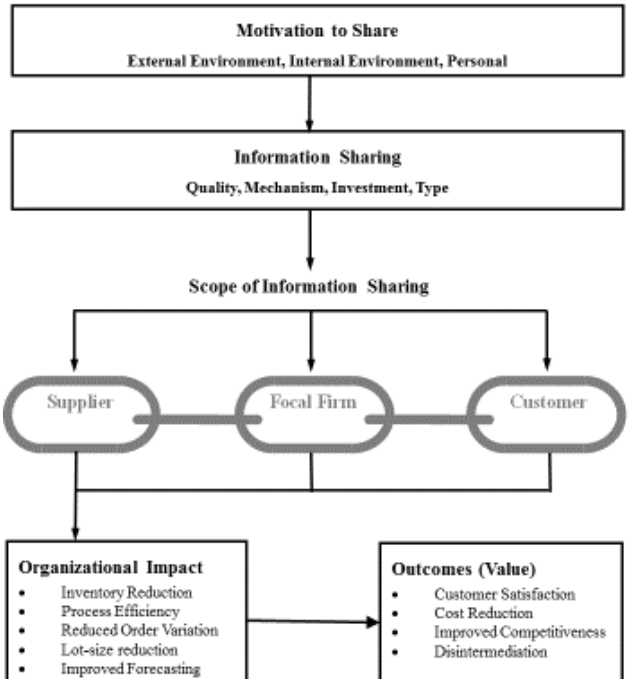

Figure 1. Information Sharing in SCM Classification Framework

Even though this topic is in the early stages of debate, it is still important to determine if there are any significant trends that have occurred in the literature for the past nine years. Figure 2 contains a clustered column trend chart of the selected articles of information sharing in supply chain management corresponding to the year of publication and the category of information sharing research. As you can see in the chart, the four categories of information sharing research are represented by a different color and are filed according to the number of publications for each category and the year of publication. Some categories of research were omitted from the chart because no literature was available for that particular year based on the classification scheme described above. The first observation that can be made from the trend chart is that research focusing on the type of information sharing dominated the early knowledge on the topic. It appears that information sharing quality research did not receive much attention during the first part of the new millennium but has gained steady ground in the years beyond 2003. You can also see that the information sharing research has tapered off in the past few years, which indicates some degree of saturation of the topic, although there is still much potential for additional research. This trend chart may provide a snap-shot of the research for the fourteen-year period, but more samples will be required to truly understand the picture of the information sharing in supply chain management literature.

In order to develop a classification model, a spreadsheet was created as the first step of the review that contains detailed information from each article, such as research method, variable list, key findings, future research opportunities, etc. The spreadsheet was then analyzed by three independent referees to identify the four categories of information sharing research identified above. Finally, each article was evaluated by the referees based on the four categories to determine the best fit for the research. The classification scheme is not designed to be mutually exclusive, as there were some articles that bridged one or more of the categories. However, each individual article was ultimately filed in only one of the information sharing categories, identified as the best fit, in order to create a parsimonious classification model. Table 1 presents a description of the articles selected for the review.

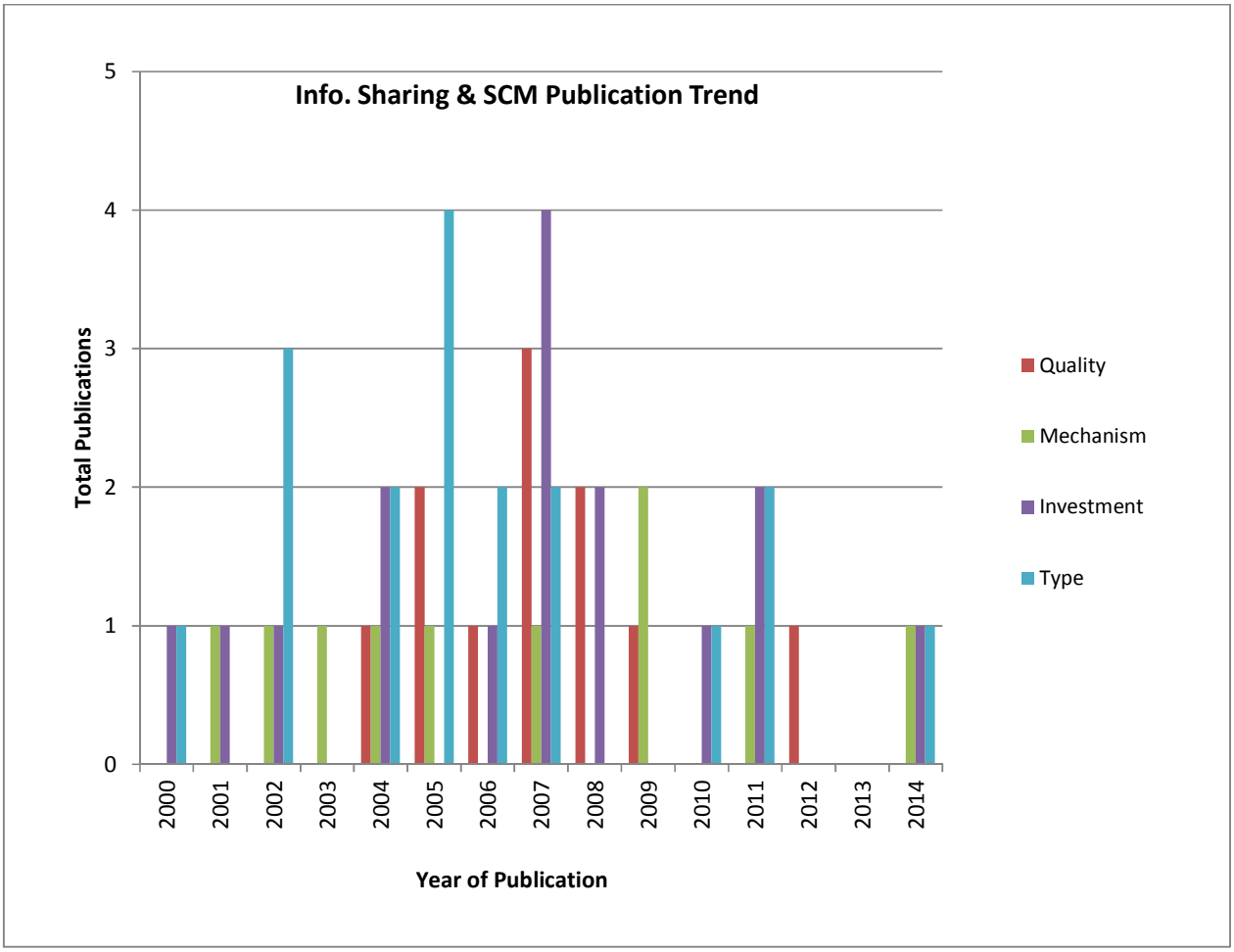

Figure 2. Publication Trend of the 55 Articles

Table 1. Literature Reviewed

Reference	Research Description
[6]	Modeling study that examines the value of sharing demand and inventory data with one supplier, N identical retailers, and stationary stochastic consumer demand
[10]	Beer Game lab experiment that investigates the impact of point-of-sale data on ordering decisions in a multi-echelon supply chain with known demand distribution
[11]	Simulation that examines the effects in supply chains of stochastic lead times, information sharing, and the quality of that information in an order-up-to level inventory system
[12]	This research employs a simulation and lab experiment to examine how order and delivery cycle changes, POS information sharing, and the pattern of customer demand affect supply chain efficiency
[13]	This paper utilizes a lab experiment in context of the "beer game" to observe the value of inventory information and the impact of the information sharing to the bullwhip effect
[17]	Utilizes a field survey to investigate the integration of information sharing and supply chain practice in supply chain management
[18]	Simulation that tests the impact of information sharing on profit in the case of perishable product freshness with known and unknown product age
[19]	Empirical study that investigates the use of EDI for interfirm coordination activities involving suppliers and customers, and considers the influence of demographic characteristics on EDI use with support from a field study.
[20]	This article explores the role of e-business technologies in SCM and collected data with a field survey to access customer and supplier integration in the supply chain and the effect on performance
[21]	Field survey that considers the relationship between organizational use of e-business technologies, organizational collaboration, and performance.
[22]	The objective of this paper is to examine a manufacturer's ordering policies and transportation activities, the vendor's manuf. and order fulfillment processes, and measure the value of information sharing and system coordination across five strategies by employing a simulation
[23]	Empirical study that examines SCM relationships between service providers and clients focusing on performance impacts of customization level and real time information access
[24]	Analytical modeling/game study that examines the incentives for firms to share demand information vertically in the presence of horizontal competition
[25]	Empirical study that investigates the effect of the institutional environment on information integration between buyers and suppliers in China.
[26]	Empirical study measuring if the level of information availability moderates problem solving approach on supply chain performance
[27]	Empirical study that examines the impact of supply chain integration on operational and business performance.
[28]	Examines the antecedents and outcomes of inter-organizational communication
[29]	Explores internal and external information linkages as it relates to operational performance
[30]	Model/Game that studies the incentives for firms to share information vertically in a two-level supply chain with an upstream manufacturer and many downstream retailers
[31]	Empirical study that develops a framework that relates information integration initiatives and their impact on inventory management and revenue-enhancing measures
[32]	Empirical study assessing different information flow strategies to enhance supply chain integration
[33]	Utilizes game theory to access the need for credible forecast information sharing between a supplier and a manufacturer
[34]	Modeling study that attempts to quantify the benefits of demand information sharing between retailers and their suppliers in a simple two-level supply chain
[35]	This paper is a note on the Lee et al. (2000) paper that analytically demonstrates the benefits of using historical order information when the parameters of the AR(1) process are known to both the manufacturer and retailer
[36]	Modeling study that investigates how the time-series structure of the demand process affects the value of information sharing in a two-level supply chain
[37]	This paper addresses the need to change the supply chain management strategy in order to make complete use of the information flows
[38]	Empirical study investigating the impact of IT investments on supply chain performance.
[39]	Modeling study that compares the performance of their model, with one supplier, multiple retailers, and demand info. sharing, to other models with no information sharing
[40]	Analytical study that investigates contracting and information sharing in two different supply chains
[41]	Investigates information sharing in decentralized supply chain with retailers competing on price
[42]	Analytical study that investigates the role of information sharing to reduce the bullwhip effect
[43]	Investigates capacity investments decisions based on shared forecasting information
[44]	Analytical study investigating incentives for vertical information sharing in competing supply chains
[45]	Investigates the impact of reliable inventory information on increased sales and traffic in stores
[46]	Investigates the relationship between trust, trustworthiness, and information sharing in China
[47]	Numerically investigates various information sharing scenarios between a manufacturer and two retailers and determines the manufacturers optimal production policy
[48]	Modeling study that examines how sharing future demand information can help companies lower cost in a two-level system with one retailer and multiple customers
[49]	A simulation is used to investigate the value of various information exchange mechanisms in a four-echelon supply chain under a material requirements planning framework.
[50]	This paper proposes a negotiation-based algorithm for solving distributed project scheduling problems with schedule flexibility information sharing
[51]	A simulation is used to access the impact of supply uncertainty on the value of information sharing with demand volatility under various scenarios
[52]	Modeling study with a simulation that designs a decentralized coordination mechanism for dynamic lot-sizing in distribution networks
[53]	Investigates the impact of information sharing of the demand mix on supply chain performance by changing customer demand pattern and production capacity
[54]	Modeling study with a simulation that examines the impacts of different levels of information sharing on the performance of supply chain project rescheduling problems
[55]	Empirical study that surveyed logistics practitioners to identify and align logistics performance measures with the information requirements of the organization
[56]	A simulation analysis studies the effect of inaccurate inventory info. and delays in replenishment decisions
[57]	Simulation model investigating the risks of demand collaboration and information manipulation
[58]	Identifies core practices and key requirements to successful supply chain collaboration
[59]	Investigates the accuracy of forecasting based on shared point-of-sale data
[60]	Field survey of Swedish companies and their suppliers to determine the impact of forecast information quality on supply chain performance
[61]	Empirical study investigating the nature of info. sharing among and across firms as a supplier development tool
[62]	Empirical study that examines information sharing as a deterrent to unethical behavior
[63]	Empirical study investigation the impact of social resources on promoting information sharing
[64]	Modeling study that examines the linkage between IT capability, firm collaboration, and performance
[65]	Analytical modeling study that evaluates the value of information in firms that face uncertainty
[66]	Investigates the benefits of EDI usage with empirical data

2.1 Classification Framework

Table 2 presents the classification of the fifty-five articles included in the literature review. The primary objective of this table is to identify the well-traveled paths of research utilizing the four categories of information sharing and the associated weight of each based on the total number of articles that concentrate on a particular aspect within each category. This table will also be used as the template for the discussion on each class and the common variables that have surfaced from the research.

As you can see in the table, the majority of the articles included in this review lie within the columns of information sharing type and information sharing investment/implementation. Information sharing mechanisms and information sharing quality research are the minority in this sample and account for a little over 1/3 of all articles published. The next few sections will provide a detailed discussion on each of the four categories of information sharing in supply chain management research and offer insights from the various authors included in the review.

Table 2. Classification of information sharing in supply chain management articles

Ref.	Quality	Mechanism / Technology	Investment / Implementation	Type
[6]			*	
[10]		*		
[11]	*			
[12]		*		
[13]				*
[17]	*			
[18]				*
[19]		*		
[20]			*	
[21]				*
[22]				*
[23]	*			
[24]				*
[25]			*	
[26]	*			
[27]				*
[28]	*			
[29]		*		
[30]			*	
[31]			*	
[32]		*		
[33]	*			
[34]				*
[35]			*	
[36]				*
[37]				*
[38]			*	
[39]				*
[40]			*	
[41]	*			
[42]		*		
[43]				*
[44]			*	
[45]				*
[46]			*	
[47]				*
[48]			*	
[49]		*		
[50]				*
[51]				*
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[61]			*	
[62]	*			
[63]		*		
[64]		*		
[65]			*	
[66]		*		
Ref.	**Quality**	**Technology**	**Implementation**	**Type**

2.1.1 Information Sharing Quality

Information sharing quality articles typically focus on the overall quality of information shared, access to the information, level of shared information (full, partial, none), and/or the effects of inaccurate information sharing. Many authors investigate the impact of asymmetric and/or poor quality information on supply chain performance. Information sharing quality research is an underrepresented area in this review and has just come into the spotlight during the past few years.

Ref. [11] employed a simulation to study the effect of information sharing, particularly the quality of information, on supply chains in a periodic order-up-to level inventory system. They examined information quality as it is used in lead-time demand forecasting and inventory parameter updating with the role that information quality may play in the bullwhip effect. Four levels of information were studied – Level 0 (no new info.), Level 1 (historical info. is available), Level 2 (historical info. and estimate of lead-time variance), and Level 3 (inventory manager tracks and stores the final lead-time demand realizations for each order). The authors determined that all information levels, except level 0, are significant aggravators to the bullwhip effect. In other words, poor information quality increases the variance or amplification of orders as they travel up the supply chain due to inaccurate forecasting.

Ref. [23] explored the supply chain management relationships between service providers and clients from the perspective of real time access to operational information that is maintained by vendors and the impact of real time information access on performance. Based on empirical evidence from a logistics service provider and 91 clients, he discovered that real time information access has a positive influence on performance of both entities. The performance measurement includes the overall economic condition of the firm, performance outcomes

that are easily measureable (productivity, operating costs, etc.) and intangible performance outcomes.

There were a couple of authors that studied information sharing levels (i.e. full-information, partial-information, no-information) and/or the quantity of information shared. Ref. [17] investigated the level of information sharing and found that "effective supply chain practice becomes more important when the level of information sharing increases". Ref. [54] examined the impacts of different levels of information sharing on the performance of supply chain project rescheduling problems and determined that moderate information sharing was better than no information sharing and full information sharing in terms of rescheduling efficiency and effectiveness.

Overall, many of the authors agree that the quality of information, level of information, and access to the shared information lead to increased supply chain performance and efficiency. This emerging information sharing perspective has a bright future in the literature and should have a strong foundation of data based on information sharing practices that are in place at industries around the world.

2.1.2 Information Sharing Mechanisms/Technology

The category of information sharing mechanisms is generally concerned with the technology or device that facilitates the information sharing process, as well as companies view and usage of the device. Articles in this category also discuss the avenue or type of information shared such as point-of-sale (POS) information.

Electronic data interchange is the most widely used mechanism for information sharing transactions in supply chain management. Ref. [19] investigated the use of EDI as an information transferring mechanism in the commercial food industry. They collected data from a field survey to study the impact of the technology on the coordination activities of suppliers and customers, as well as the firm's opinion of EDI. They also examined the effect of demographic characteristics on the use of EDI. They concluded that many firms view EDI as a tool for traditional transactions (e.g. invoices and purchase orders) that can increase efficiency of the operation instead of a tool that can be used to facilitate information sharing and supply chain coordination.

Ref. [49] examined the value of different information sharing mechanisms on a four level supply chain under a material requirements planning framework. A simulation is used to compare the impact of the various information mechanisms with a zero information sharing policy that requires each echelon to forecast its production and manage inventories based on historical demand information. They determined that information integration among the four supply chain levels resulted in the lowest average inventory level for each member, but the historical demand history policy resulted in the lowest total cost.

The lowest percentage of research in this review dealt with information sharing technology and mechanisms. This suggests that either, the technology used to facilitate information exchange has not changed much and has not received an abundant amount of attention in the literature, or the information sharing technology research was omitted from this review because the articles are typically targeted to more technical or computer-based series of journals. Either way, it appears that there is tremendous opportunity for future information sharing technology and/or mechanism research based on the limited number of articles identified in this review.

2.1.3 Information Sharing Investment/Implementation

An aspect of information sharing in supply chain management that has received moderate coverage in the literature is information sharing investment and implementation. Articles in this category discuss the information sharing implementation process, the need for information sharing, develops frameworks for information sharing implementation and other types of information sharing investments. Many papers focus on the benefits the companies receive from the implementation of some type of information sharing process or system.

Ref. [6] studied the value of information sharing implementation in a modeled supply chain with one supplier, multiple identical retailers, and stationary stochastic consumer demand. They accomplish this by comparing the information sharing investment with the traditional policy of no-information sharing. They found that investment in information sharing technology can reduce supply chain costs by an average of 2.2%. While this percentage may seem low by some standards, it is limited to the assumptions in their model with the underlying point of demonstrating savings generated by information sharing. Another interesting finding from their study was that investment in other forms of IT to reduce batch sizes and lead times will significantly reduce operating costs even more so than information sharing.

Ref. [31] conducted an empirical study to develop a framework for information integration investments and their effect on manufacturer profitability. They focused primarily on the impact to inventory management as well as other cost-saving measures that directly influence manufacturer profitability. They discovered that sharing information will definitely lead to increased performance but other measures and investments will be required to launch the firm to well above average profitability. This finding is based on the sample used in their survey with the companies practicing the information sharing activities reporting average profitability compared to those that did not participate in any information sharing or collaboration program reporting below average profitability.

One author published a piece that disputed the need for information sharing investment. Ref. [35] responded to an article published in Management Science by ref. [34] that advocated investment in information sharing to obtain inventory and cost reductions. Ref. [35] argued that investment in information sharing is not necessary when there is adequate information available from previous orders for the manufacturer to make sounds decisions and reduce their forecasting variance. The point was illustrated with an analytical model and the model was subsequently supported with a simulation.

2.1.4 Information Sharing Type

Information sharing type articles represent the majority class of research compiled for this literature review. Articles in this category typically concentrate on the process/strategy changes spurred by information sharing such as lot-size and inventory reductions, the organizational value of information sharing, and performance improvements from information sharing.

Many authors investigate the impact of demand information sharing on an operational measurable or processes such as inventory management or batch size reduction. Ref. [34] constructed a mathematical model to quantify the benefits of demand information sharing between retailers and their suppliers in a two-level supply chain with non-stationary end demands. They conclude that manufacturers can achieve tremendous cost and inventory reductions with demand information sharing initiatives. Ref. [67] considered information flow in a traditional supply chain with a retailer and supplier. They determined that the information flow is beneficial in terms of cost reduction due to reduced inventory levels and holding costs in addition to increased capacity. Ref. [68] investigated the value of centralized demand information in a serial inventory system under two scenarios: echelon stock and installation stock. The echelon stock policy requires centralized demand information and the installation stock policy does not. He first optimized each system then calculated the value of centralized demand information as the cost difference between the echelon stock policy and the installation stock policy. The mean value was 1.75% with a range of 9% and increased as tangible variables like lead time and batch size decrease.

Behavioral research was scarce in the population of articles selected for this literature review. One piece that stuck out among the others was published by ref. [13]. They conducted a lab experiment in the context of the popular "beer game" to determine if there are behavioral causes of the bullwhip effect and the role that information sharing plays in a serial supply chain subject to information lags and stochastic demand. Interestingly, they discovered that the bullwhip effect remains when inventory level information is shared due to a tendency of underweighting (discounting orders that have been placed but not delivered). Their ultimate conclusion was that inventory information does help upstream suppliers prepare for fluctuations, but it has a minimal impact on the bullwhip effect, even when conditions are optimal, because of cognitive limitations of managers.

Overall, it appears that information sharing type articles receive the most attention in the literature (the four papers mentioned above have been cited over 800 times combined) due to the content of the articles and the industry related applications found in nearly every piece. They represent nearly 50% of the articles in this review and continue to provide rich direction for practitioners and researchers alike. There are many possible extensions to information sharing type related articles that can lend valuable insight to this plentiful topic.

3. Methodology

Utilizing secondary data, this paper surveys the literature relative to the impact of information sharing, exchange, and integration on supply chain management activities. The purpose of this research is to analyze and synthesize the available literature to aid researchers or practitioners that may be interested in aspects of information sharing in supply chain management.

Articles selected for review have been published in the premier Operations Management and Supply Chain Management journals since the year 2000. The journals included in the search are: *Management Science, Operations Research, Journal of Operations Management, International Journal of Production Research, Production and Operations Management, International Journal of Operations and Production Management, Journal of Supply Chain Management, and the Journal of Business Logistics*. Selection criteria for the journals is based on the ranking of the supply chain and operations management journals from the Australian Business Deans Council 2013 Journal Quality List [69]. Textbooks, conference papers, dissertations, and unpublished working papers were excluded from the review.

A search was conducted via the web (Google Scholar) as well as other online databases (Proquest, EBSCOhost, etc.) to identify articles for inclusion in this study based on the following keywords and phrases: *Information Sharing Supply Chain, Information Exchange, Communication, Collaboration, and Value of Information*. In total, 122 articles were collected from the search process. Each paper was screened for its relevance to the subject and filtered accordingly. The screening process revealed fifty-five articles that will be included in the review. Although fifty-five articles is not an exhaustive collection of articles, many other studies that review supply chain management research have been published based on a review of far fewer articles than fifty-five (e.g. [70], [71], [72]). Therefore, the author contends that the fifty-five articles available and collected for this study provides adequate context to capture the relevant dimensions and paths of information sharing research.

4. Discussion/Results

Information sharing in supply chain management has been investigated from many different angles at the start of the new millennium. There is an ample amount of literature available in a variety of journals utilizing nearly every research method possible. Even with the abundance of research, there are still areas that require additional investigation.

This review uncovered very little experimental research. Ref. [13] conducted a lab experiment in the context of the popular "beer game" to determine if there are behavioral causes of the bullwhip effect and the role of information sharing. It would be interesting to extend this work to full and open information sharing where all

members of the supply chain have access to the information as well as an individual supply chain member's reaction to the information. Are there other behaviors, other than the "underweighting" found by ref. [13] that contribute to the bullwhip effect? Are there biases in the decision making process? These questions and other could be answered by conducting the experiment in an open classroom on a game board or in a computer lab.

Vendor-managed inventory (VMI), where the supplier is responsible to manage the retailer's inventory, is gaining traction in industry. What is the advantage of a vendor-managed inventory system vs. a traditional inventory system with information sharing? There is opportunity for many optimization studies based on the two inventory platforms with different assumptions. Can the two systems co-exist in the same retailer?

Ref. [24] introduced the information "leakage effect", which is the tendency for a manufacturer to leak the information that was shared by the retailer to other competing manufacturers based on their reaction and subsequent process changes due to the information. There has been very little research on this topic, so it would be interesting to determine how this leakage effect may impact horizontal competition, retailer performance, or market share.

Other avenues of future research include additional information sharing quality and mechanisms research. These two categories were the least represented in the literature which opens the door to additional work. There were very few case studies unearthed in this review. A case study in a well-established firm with information sharing policies in place may provide valuable insight to the topic of discussion. There is need for additional research and optimizations of the information sharing levels (no-information, partial-information, and full-information) and the possible advantages / disadvantages from each policy. The above suggestions represent a few ideas for the future of information sharing in supply chain management research, but they are not intended to be an exhaustive list of all possible future research paths. The vast nature of the topic inherently dictates research in many forms and directions.

There are several limitations to this study. First, the literature review was limited to only the premier and highly ranked operations management journals. It is almost certain that many insightful and groundbreaking articles have been published in journals that were not included in this search and could lend valuable information to this study. Another issue with this approach is the fact that only fifty-five articles were retrieved from the search process. This could partially be attributed to the nature and focus of the journals included in the review (i.e. Management Science maintains a quantitative focus and publishes a large number of operation research studies and not as many that are supply chain related). Fifty-five articles can provide a snap-shot of the current research landscape but may be considered too few to establish long-term themes.

Another limitation is the age of the literature and topic. Supply chain management is an ever evolving field and information sharing in supply chain management is just one avenue of research in this vast discipline. The immature nature of the topic leads to undeveloped work that is just starting to scratch the surface. Therefore, it is tough to establish a classification scheme for articles that are no more than ten to fifteen years old.

Finally, as mentioned above, the classification scheme is subjective and one could argue and most likely support an alternative to the classification approach utilized for the literature analysis. There are many different aspects to information sharing in supply chain management research. An attempt was made in this paper to classify the articles in broad categories that are both diverse and distinct from one another.

5. Conclusion

The purpose of this research is to classify the research on information sharing in supply chain management. There are very few studies that review the literature associated with information sharing in the supply chain. All of the prior studies are either outdated or are too focused on individual elements of information sharing, which reinforces the relevance and novelty of this study. The results of this study provide a roadmap for additional avenues of information sharing research. This study also provides a frame of reference for practitioners as they pursue information exchange as part of the supply chain management strategy. The type of information shared among supply chain entities is well represented in this study, which demonstrates the importance to practitioners of developing a sound strategy to share relevant information (forecasts, inventory levels, production quantities, etc.) among all member s of the supply chain. There are generally four categories of the information sharing literature: quality, mechanisms, investment, and type. Information sharing quality articles typically focus on the overall quality of information shared, whereas information sharing mechanism associated papers discuss the technology or device that facilitates the information sharing process. Information sharing investment articles discuss the information sharing implementation process, the need for information sharing. Finally, the element of information sharing type was the most populated group and typically concentrate on process/strategy changes spurred by information sharing, the organizational value of information sharing, and performance improvements from information sharing.

There are many different available paths for future research. Empirical research has received scant attention in the literature; therefore there are many opportunities for additional empirical research. One interesting path is experimental work in the context of the "beer game". Other directions that require further investigation include additional information sharing quality and mechanisms research, case studies, and optimizations of the information sharing levels (no-information, partial-information, and full-information).

Based on the hundreds of research papers that investigate information sharing in supply chain management during the brief start to the new millennium, there is a rich history of research that has no apparent end in sight. Hopefully, the literature review presented here

and the questions that remain unanswered will stimulate additional research in the fruitful information sharing arena.

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