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# Supply Chain Logistics Management

*Fifth Edition*

**Donald J. Bowersox**
**David J. Closs**
**M. Bixby Cooper**
**John C. Bowersox**
*Michigan State University*

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This book is dedicated to the memory of Dr. Donald J. Bowersox, visionary, mentor, and friend and one of the founders of the academic disciplines of logistics and supply chain management. Don passed away as the fourth edition was being completed, but his legacy lives on in this fifth edition. Don's legacy will live on through the many contributions to the theory and practice of logistics and supply chain management that will continue through his family, students, and colleagues.

The authors would also like to recognize their families for their encouragement and patience because they ultimately pay the dearest price.

# About the Authors

**Donald J. Bowersox** (1932–2011) is the former University Professor and Dean Emeritus at Michigan State University. He received his Ph.D. at Michigan State and worked with industry throughout this career. He is the author of numerous articles in publications such as the *Harvard Business Review, Journal of Marketing, Journal of Business Logistics,* and *Supply Chain Management Review*. Bowersox was the co-author of what is widely recognized as the first Supply Chain academic text: *Physical Distribution Management—Logistics Problems of The Firm,* first published in 1961. He is the co-author of *Start Pulling Your Chain: Leading Responsive Supply Chain Transformation,* published in 2008. Throughout this career, Bowersox led a number of industry-supported research studies investigating the best practices of Logisticians in North America and around the world. Bowersox is recognized by many as the "Grandfather of Supply Chain" and was recognized by the Council of Supply Chain Management (CSCMP) receiving both the Distinguished Service Award (1966) and in 2011, after his death, with the renaming of the annual Doctoral Symposium in his honor as the Donald J. Bowersox Doctoral Symposium. Don's memory and many accomplishments are cherished and live on in his family, friends, and industry peers.

**David J. Closs** is the John H. McConnell Chaired Professor of Business Administration and former Chairperson in the Department of Supply Chain Management at Michigan State University. He received his Ph.D. in marketing and logistics from Michigan State. Dr. Closs is the author and coauthor of many publications in journals, proceedings, and industry reports. He was also a principal researcher for *World Class Logistics: The Challenge of Managing Continuous Change* and *21st Century Logistics: Making Supply Chain Integration a Reality.* Dr. Closs is a frequent speaker at industry and academic conferences and presenter at executive education programs. Dr. Closs formerly served as the editor of the *Journal of Business Logistics.*

**M. Bixby Cooper** is an Associate Professor emeritus in the Department of Supply Chain Management at Michigan State University. He is coauthor of three texts on distribution and logistics, including *World Class Logistics: The Challenge of Managing Continuous Change* and *Strategic Marketing Channel Management.* He is also coauthor of *Managing Operations Across the Supply Chain* published by McGraw-Hill. He served for four years on the Executive Board of the International Customer Service Association as head of the Research and Education Committee.

**John C. Bowersox** is the Director—Inbound Transportation for True Value Company. He is a graduate of Michigan State University. John is currently responsible for the Strategic and Operational oversight of True Value's Global Inbound Logistics program. Prior to joining True Value, John worked for the Kohler Co., where he held positions in Operations, Customer Service, Logistics, and Strategic Purchasing within the company's Kitchen and Bath Americas as well as Ann Sacks Tile & Stone operating divisions. Mr. Bowersox, in conjunction with his brother Ed and late father Donald, was the recipient of the DSC Movers and Thinkers Award for Innovation in Supply Chain Management. He is an active member of the Council of Supply Chain Management Professionals (CSCMP), a charter member of the Young Professionals Committee, and prior member of the Board of Directors. A close follower of academic and industry research, he is a frequent contributor at industry conferences.

# Preface

Over the last eight decades, the discipline of business logistics has advanced from the warehouse floor and transportation dock to the boardroom of leading global enterprises. We have had the opportunity to be actively involved in this evolution through research, education, and advising. *Supply Chain Logistics Management* encompasses the development and fundamentals of the logistics discipline within a supply chain framework. It also presents our vision of the future for business logistics and supply chain management and their role in enterprise competitiveness.

Although individually and collectively the four authors have written extensively on various aspects of logistics and supply chain management, the decision to initially write and subsequently revise *Supply Chain Logistics Management* represents the synthesis of many years of research, augmenting and, in many ways, supplanting earlier works of the authors published by McGraw-Hill. The union of ideas presented in this text provides an integrated supply chain framework for the study of logistics, serves to expand the treatment of supply chain management by placing it firmly in the context of integrated business strategy, and highlights the increasing importance of logistics in the supply chains supporting a global economy.

Logistics includes all the activities required to move product and information to, from, and between partners in a supply chain. The supply chain provides the framework for businesses and their suppliers to jointly deliver goods, services, and information efficiently, effectively, relevantly, and in a sustainable manner to consumers. *Supply Chain Logistics Management* presents the mission, business processes, and strategies needed to achieve integrated logistical management. We hope the text achieves three fundamental objectives: (1) presents a comprehensive description of existing logistical practices in a global economy, (2) describes ways and means to apply logistics principles to achieve competitive advantage, and (3) provides a conceptual approach for integrating logistics as a core competency within enterprise supply chain strategy.

This edition has benefited greatly from thoughtful suggestions from students, colleagues, and reviewers. We note several changes and additions to this new edition:

- Incorporated a section in Chapter **1** that discusses the broad application of logistics and supply chain management to include other applications beyond movement of goods.
- Incorporated considerations for value chain management in the text.
- Reviewed supply chain information technology in Chapter 2 to provide a broad perspective and then again reviewed the relevant technologies in the application chapters.
- Discussed regarding how consumer and technology disrupters will impact logistics and supply chain management.
- Condensed discussion of procurement and manufacturing into one chapter focusing on strategy and interfaces with logistics.
- Incorporated forecasting and planning into a single chapter focuses on integrated operations planning.
- Included updated materials regarding transportation pricing; negotiation; regulation; and modern trends, challenges, and opportunities.
- Synthesized the discussion of handling and packaging with warehousing.
- Expanded the global strategy and operations chapter to include discussion of compliance.

- Expanded the discussion of supply chain network design to include principles that can be applied in nontraditional settings and the major drivers in supply chain design.
- Discussed the future trends in logistics and supply chain management in the final chapter.

Over the past 53 years, the business executives who have attended the annual Michigan State University Logistics Management Executive Development Seminar have been exposed to the basic concepts presented in the text and have given freely of their time and experience. We also acknowledge the long-standing support to Michigan State Department of Supply Chain Management, through the funding of the endowed chairs, provided by the late John H. McConnell, founder of Worthington Industries, and Rob Thull, who is the primary donor for the Bowersox-Thull Chair in Logistics and Supply Chain Management.

The number of individuals involved in teaching logistics around the world expands daily. To this group in general, and in particular to our colleagues at Michigan State University, whose advice and assistance made it possible to complete and enhance this text, we express our sincere appreciation.

Teachers receive continuous inspiration from students over the years, and in many ways the day of judgment in an academic career comes in the seminar or classroom. We have been fortunate to have the counsel of many outstanding young scholars who currently are making substantial impact on the academic and business worlds. In particular, we appreciate the input of students who have used this text in manuscript form and made suggestions for improvement. We also acknowledge the contributions of Drs. Judith Whipple, Stan Griffis, Yem Bolumole, and Thomas Goldsby, who contributed extensively in case and concept development.

We would like to thank the following instructors for their thoughtful contributions to the previous edition review: Gurkan Akalin, Joe T. Felan, EunSu Lee, Penina Orenstein, Thomas Passero, James L. Patterson, Frank R. Scheer, and George Young.

We wish to acknowledge the contributions of Felicia Kramer and Pamela Kingsbury, for manuscript preparation on several earlier versions of this text, and Cheryl Lundeen, who prepared many drafts of the manuscripts. Without Felicia, Pam, and Cheryl, this long-published text in its many variations would not be a reality.

With so much able assistance, it is difficult to offer excuses for any shortcomings that might appear. Any faults are solely our responsibility.

*David J. Closs*

*M. Bixby Cooper*

*John C. Bowersox*

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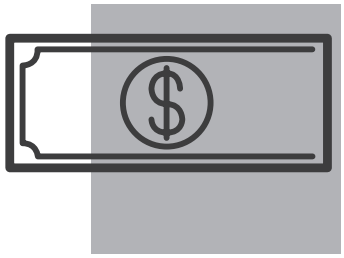



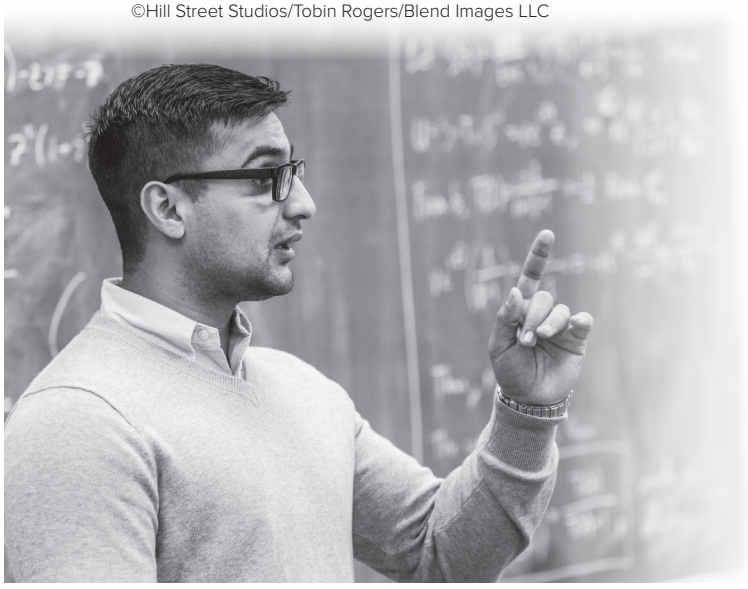

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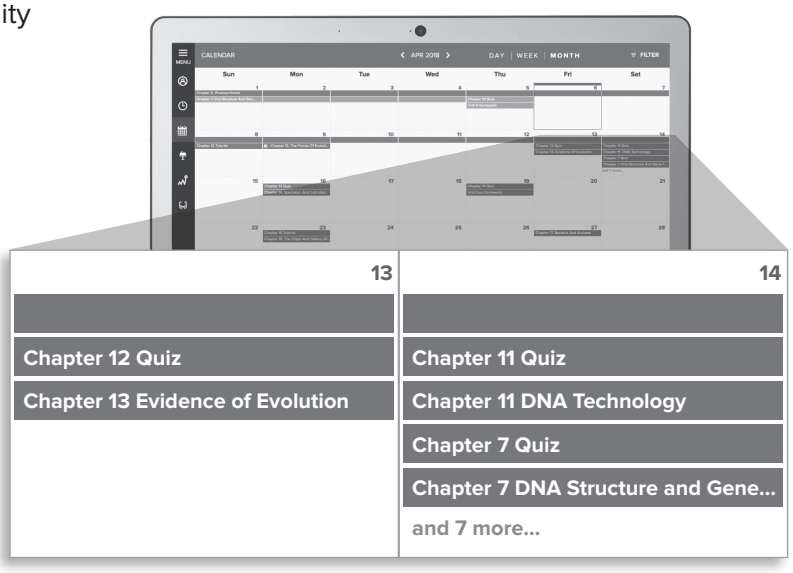


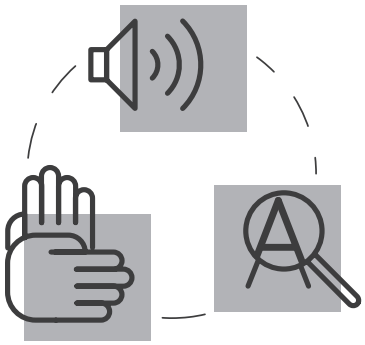

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# Brief Contents

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# Supply Chain Logistics Management

CHAPTER 2

# Supply Chain Information Technology

**Chapter Outline**



New advances in information technology have introduced many new opportunities for supply chain and logistics strategy and operations. Since 2000, the world of commerce has been irrevocably affected by computer miniaturization, the Internet, a range of inexpensive information transmission capabilities, and omni-channel supply chain operations. Information characterized by speed, accessibility, accuracy, relevancy, and simplified access are now the norm. The Internet is a common and economical means to complete business-to-business (B2B) and business-to-consumer (B2C) transactions. Internet browsers have become the default standard for exchanging transactions and data between supply chain partners. Three-dimensional (3D) printing has even made it possible for physical products to be transferred across the Internet. Global Internet capability and standardization also facilitates worldwide execution and tracking.

What began during the last decade of the 20th century and will continue to unfold well into the 21st century is what historians are increasingly characterizing as the dawning of the information or digital age. The reality of the digital age is the connectivity among collaborating business organizations, which will continue to drive supply chain management advancement. Managers are increasingly enhancing and integrating traditional marketing, manufacturing, purchasing, and logistics practices. In this new order, products and solutions can be developed to exact specifications and rapidly delivered to customers throughout the globe. Logistical systems exist that have the capability to delivery products/solutions at precise times. Customer order and delivery of product assortments can be performed in hours. The frequent occurrence of service failures that characterized the past are increasingly being replaced by a growing managerial commitment for zero defect or what is commonly called six-sigma performance. Perfect orders—delivering the desired

assortment and quantity of products to the right location, on time, damage-free, and correctly invoiced—once the exception, are now becoming the expectation. Perhaps most important is the fact that such high-level performance is being achieved at lower total cost and with the commitment of fewer financial resources that was required in the past. All of this fundamental change in business enterprise structure and strategy is primarily being facilitated by information technology.

While many supply chain and logistics texts segment the discussion of information technology over multiple chapters so that the material is discussed in the chapter to which it applies, this text introduces a supply chain information technology framework so the reader can understand the role of information technology in supply chain design, strategy, and execution. This framework offers the big picture of supply chain information technology while later chapters provide more detail regarding the individual technology modules.

This chapter describes the supply chain information technology framework discussed above. Each framework component is discussed in detail in the following sections.

## Information System Functionality

A major enabler of supply chain planning and execution is information technology. Supply chain technology systems initiate activities and track information regarding processes, facilitate information sharing both within the firm and between supply chain partners, and assist in management oversight and decision making. Comprehensive information systems are a combination of transaction, decision support, and communication components.

From its inception, logistics focused on product storage and flow through the supply chain. Information flow and accuracy were often overlooked because they were not viewed as being critical to customers. In addition, information transfer rates were limited to mail or manual processes. There are five reasons timely and accurate information has become more critical in supply chain design and operations. First, customers perceive information regarding order status, product availability, delivery tracking, and invoices as necessary dimensions of day-to-day business operations. Customers demand real-time information. Second, with the goal of managing total supply chain assets, managers realize that information can be used to reduce inventory and human resource requirements. In particular, requirements planning based on timely information can reduce inventory by minimizing demand uncertainty. Third, information increases flexibility with regard to how, when, and where resources may be utilized to achieve competitive advantage. Fourth, enhanced information transfer and exchange utilizing the Internet is facilitating collaboration and redefining supply chain relationships. Finally, with the increasing demand to remove uncertainty and variation from the supply chain, there a corresponding increase in demand to enhance inventory transparency and visibility. A common example of comprehensive information systems driving better supply chain utilization may be found in today's international shipping arena. It is common for a firm to redirect a container mid-transit based on real-time feedback from local markets. This change, enabled by information technology results in higher service levels and simultaneously improved asset utilization.

**Supply chain information systems (SCISs)** are the thread linking logistical activity into an integrated process. Integration builds on four levels of functionality: (1) transaction systems, (2) management control, (3) decision analysis, and (4) strategic planning. Figure 2.1 illustrates logistics activities and information required at each level. As the pyramid shape suggests, management control, decision analysis, and strategic planning enhancements require a strong transaction system foundation.

A **transaction system** is characterized by formalized rules, procedures, and standardized communications; a large volume of transactions; and an operational, day-to-day focus. The combination of structured processes and large transaction volume places a major emphasis

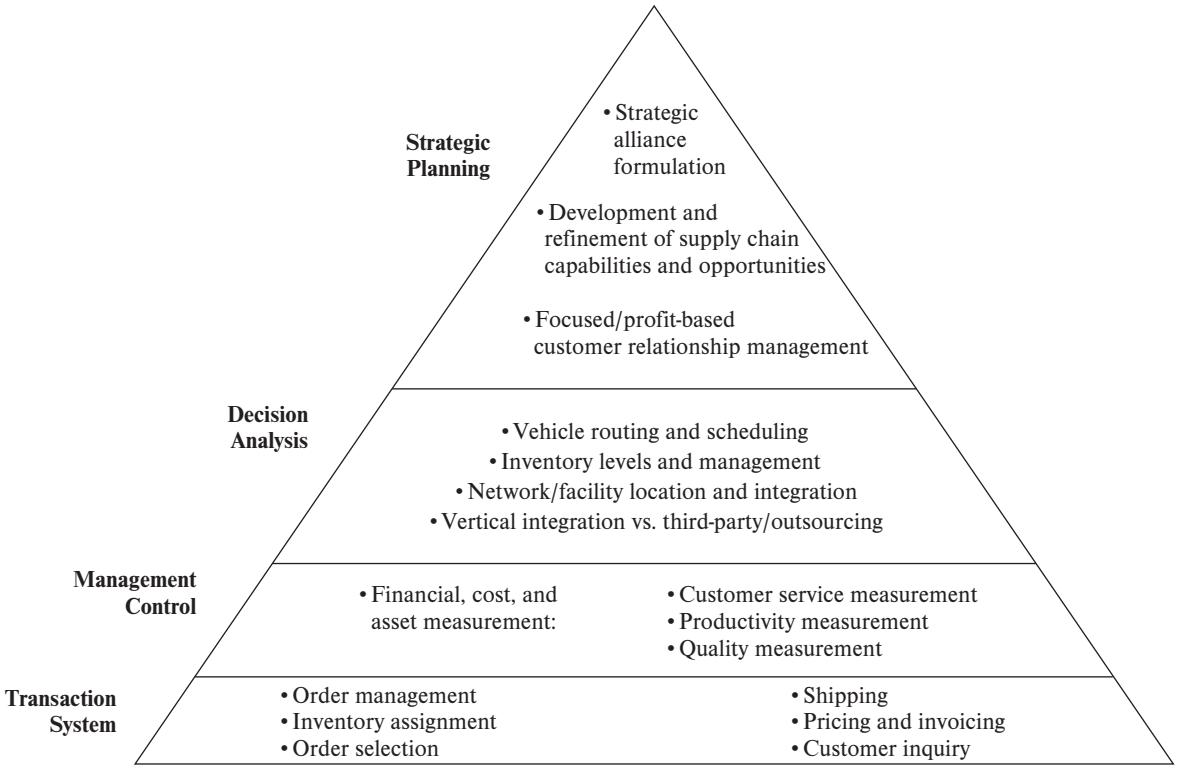


**FIGURE 2.1** Supply Chain Information System Functionality

on information system efficiency. At the most basic level, transaction systems initiate and record individual logistics activities and their outcomes. Typical transaction functionality includes order entry, inventory assignment, order selection, shipping, pricing, invoicing, and customer inquiry. For example, customer order entry represents a customer request for products into the information system. Order entry transaction initiates a second transaction as inventory is assigned to the order. A third transaction is then generated to direct warehouse operations to select the order. A fourth transaction initiates order shipment to the customer. A final transaction creates the invoice and a corresponding account receivable. Throughout the process, the firm and customer expect real-time information regarding order status. Thus, the customer order performance cycle is completed through a series of information system transactions.

The second SCIS level, **management control**, focuses on performance measurement and reporting. Performance measurement is necessary to provide feedback regarding supply chain performance and resource utilization. Common performance dimensions include cost, customer service, productivity, quality, and asset management measures. As an example, specific performance measures include transportation and warehousing cost per hundredweight, inventory turnover, case fill rate, cases per labor hour, and customer service level.

While it is necessary that the SCIS report historical system performance, it is also necessary for the system to identify operational exceptions. Exception information is useful to highlight potential customer or operational problems. For example, a proactive SCIS should be capable of avoiding future inventory shortages based on forecast requirements and planned inventory. Exception reporting should also identify potential transportation, warehouse, or labor constraints. While some control measures, such as cost, are well defined, other measures, such as service and quality, may be less specific. For example,

customer service can be measured internally, from the enterprise's perspective, or externally, from the customer's perspective. While internal measures are relatively easy to track, information concerning external measures is more difficult to obtain, since it involves the customer or other external partners.

The third SCIS level, **decision analysis**, focuses on software tools to assist managers in identifying, evaluating, and comparing strategic and tactical alternatives to improve performance. Typical analyses include supply chain design, inventory management, resource allocation, transportation routing, and customer segment profitability. Decision analysis SCISs should ideally include database maintenance, modeling, analysis, and reporting. Like management control, decision analysis may include operational considerations such as vehicle routing and warehouse planning. Decision analysis is also being used to manage customer relationships by determining the trade-offs associated with having satisfied and successful customers.

**Strategic planning**, the final SCIS level, organizes and synthesizes transaction data into a relational database that assists in strategy formation and evaluation. Essentially, strategic planning focuses on information to evaluate and refine supply chain and logistics strategy. Examples of strategic planning include the desirability and scope of strategic alliances, development and refinement of supply chain capabilities, and opportunities related to customer relationship management. The relative shape of Figure 2.2 illustrates SCIS development characteristics and justification. Development and maintenance costs include hardware, software, communications, and human resources. In the past, most systems development focused on improving transaction system efficiency. While these investments originally offered returns in terms of speed and lower operating costs, there are now fewer improvement opportunities. Most SCIS development and implementation is now focused on enhanced supply chain system integration and improved decision making.

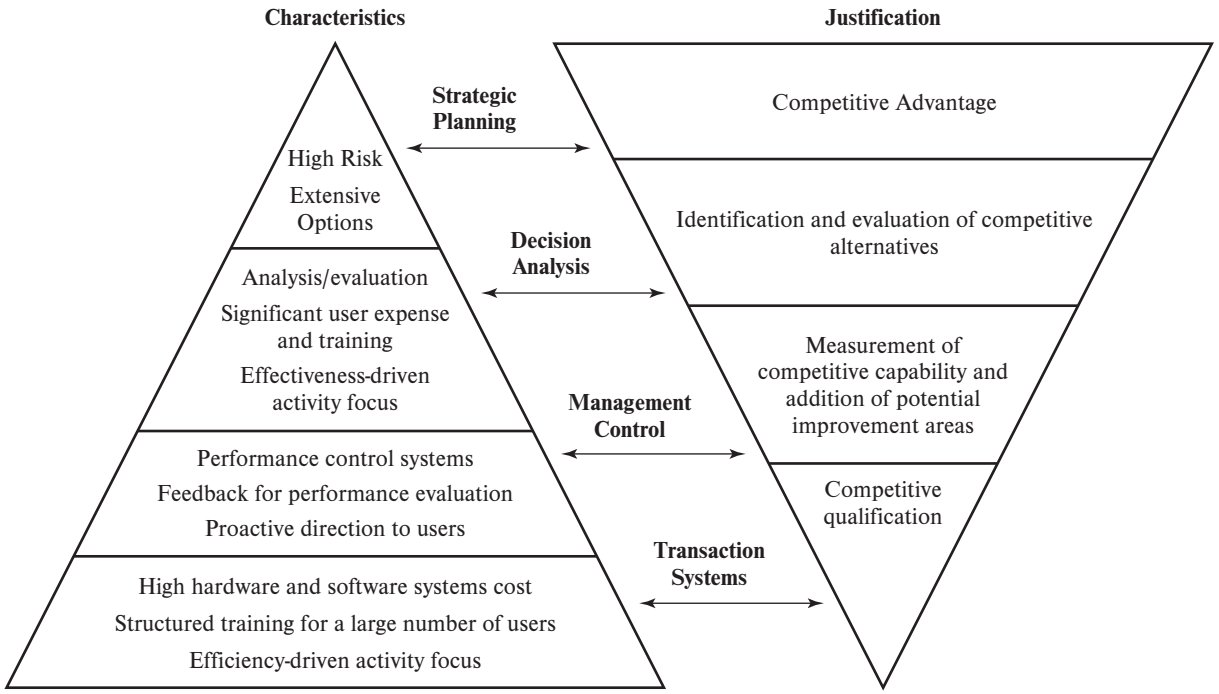


**FIGURE 2.2** SCIS Usage, Decision Characteristics, and Justification

# Supply Chain Information System Modules

A comprehensive SCIS initiates, monitors, assists in decision making, and reports on activities required for completion of supply chain operations and planning. The major system modules and their interfaces are: (1) **enterprise resource planning (ERP)**, (2) communication systems, (3) execution systems, and (4) planning systems. Figure 2.3 illustrates a more application-oriented perspective. This application perspective is used to discuss each module's specific characteristics and functionality.

The ERP systems in Figure 2.3 are the backbone of most firms' logistics information system. This backbone maintains current and historical data and processes to initiate and monitor performance. During the 1990s, many firms began to replace self-developed functional modules (called "legacy systems") with ERP systems designed as integrated transaction modules and processes with a common and consistent database. The database includes information storage capability for both operations (i.e., product and activity based) and financial (i.e., monetary based) transactions. ERP systems facilitate integrated operations and reporting to initiate, monitor, and track critical activities such as order fulfillment and replenishment. ERP systems also incorporate an integrated corporatewide database, sometimes referred to as a data warehouse, along with appropriate transactions to facilitate logistics and supply chain planning and operations. Supply chain transactions facilitated by ERP systems include order entry and management, inventory assignment, and transportation. Beyond these supply chain applications, ERP systems typically include financial, accounting, and human resource capability. Data mining, knowledge management, and other enterprise integration applications operate using the ERP backbone to develop and organize insight regarding customers, products, and operations.

## Enterprise Integration and Administration

Enterprise integration and administration are ERP modules that are not specifically supply chain applications. However, supply chain operations do have substantial interaction with these ERP components. Figure 2.4 illustrates the major enterprise integration and administration components. They are (1) general administration, (2) accounts receivable and payable, (3) financial inventory accounting, (4) general ledger, and (5) human resources.

General administration includes the various transactions to structure the firm and define transaction process flows. Supply chain operations use these modules to define

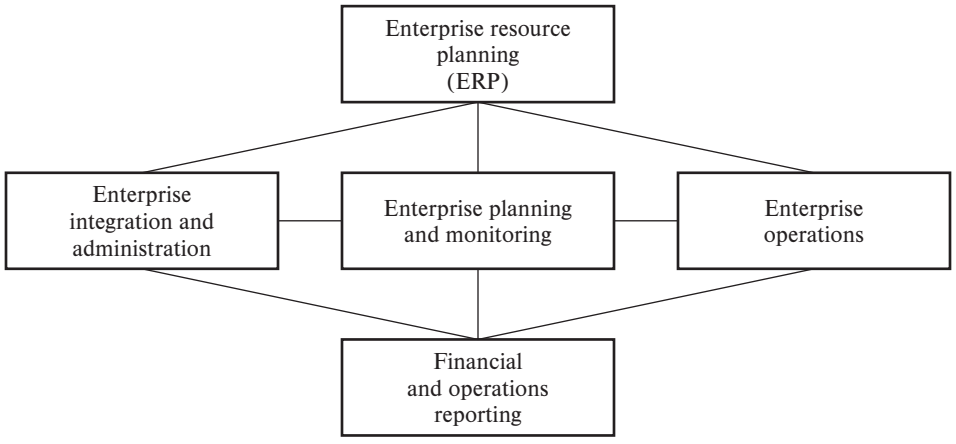


**FIGURE 2.3**
Application-Oriented SCIS Framework

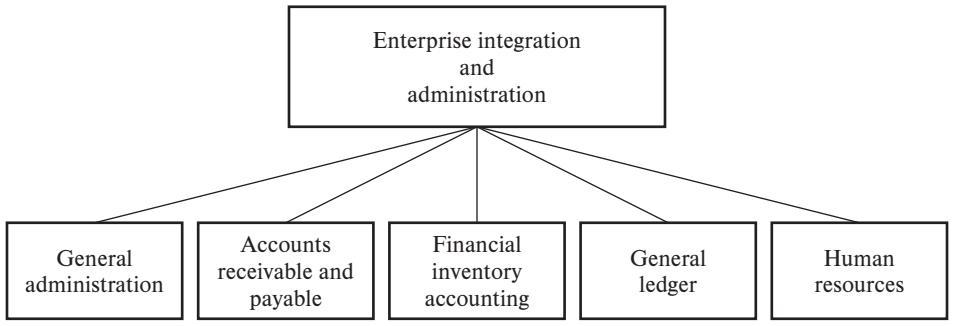


**FIGURE 2.4**
Enterprise Integration and Administration Components

reporting, functional, and organizational structures as well as to define process flows such as customer and replenishment order fulfillment. Accounts receivable and payable represent the functions for invoice collection from customers and invoice payment to suppliers. While these are typically acknowledged as accounting functions, there is a significant interaction with supply chain operations since accounts payable is influenced by materials and services acquisition and accounts receivable is influenced by delivery and invoicing of complete orders. Financial inventory accounting relates to the tracking of value-added processes through the supply chain to facilitate financial and tax reporting. The timing and location of supply chain value-added processes (e.g., production, inventory control, and packaging) can have a significant influence regarding what can be reported to the treasury (for taxation purposes) and the financial markets (for stock valuation purposes). General ledger relates to the structure of the detailed accounts for monitoring and reporting revenues and accounts. Since supply chain involves substantial interaction with firm and external processes, the structure of the general ledger accounts significantly influences the supply chain's ability to measure, monitor, and report cost related to delivering product or serving customers. The human resource module of the ERP systems tracks personnel profiles and their activity levels. Since most firms have a large number of individuals involved in supply chain operations (e.g., manufacturing, logistics, and purchasing) and often in different global environments, the ability to track pay scales and activity levels is critical to make effective supply chain personnel decisions.

## Enterprise Supply Chain Operations

Enterprise operations include the SCIS modules required to support day-to-day supply chain operations. Figure 2.5 illustrates the specific modules, including: (1) customer relationship management, (2) logistics, (3) manufacturing, (4) purchasing, and (5) inventory deployment. Enterprise operations systems work in conjunction with the firm's ERP system to provide specific functionality to support supply chain operations. While some ERP systems support required supply chain functionality, others lack some functionality such as that required to support warehouse and transportation operations.

**Customer relationship management (CRM)** systems, are applications designed to facilitate information sharing between customers, sales force, and operations management. The logistics module directs and monitors logistics activities including finished goods inventory management, warehouse management, transportation management, and yard management. The manufacturing module schedules and allocates production resources and determines component requirements. The purchasing module initiates and tracks procurement activities including purchase order initiation, expediting, and supplier management. The inventory deployment system module schedules and monitors material flows to meet

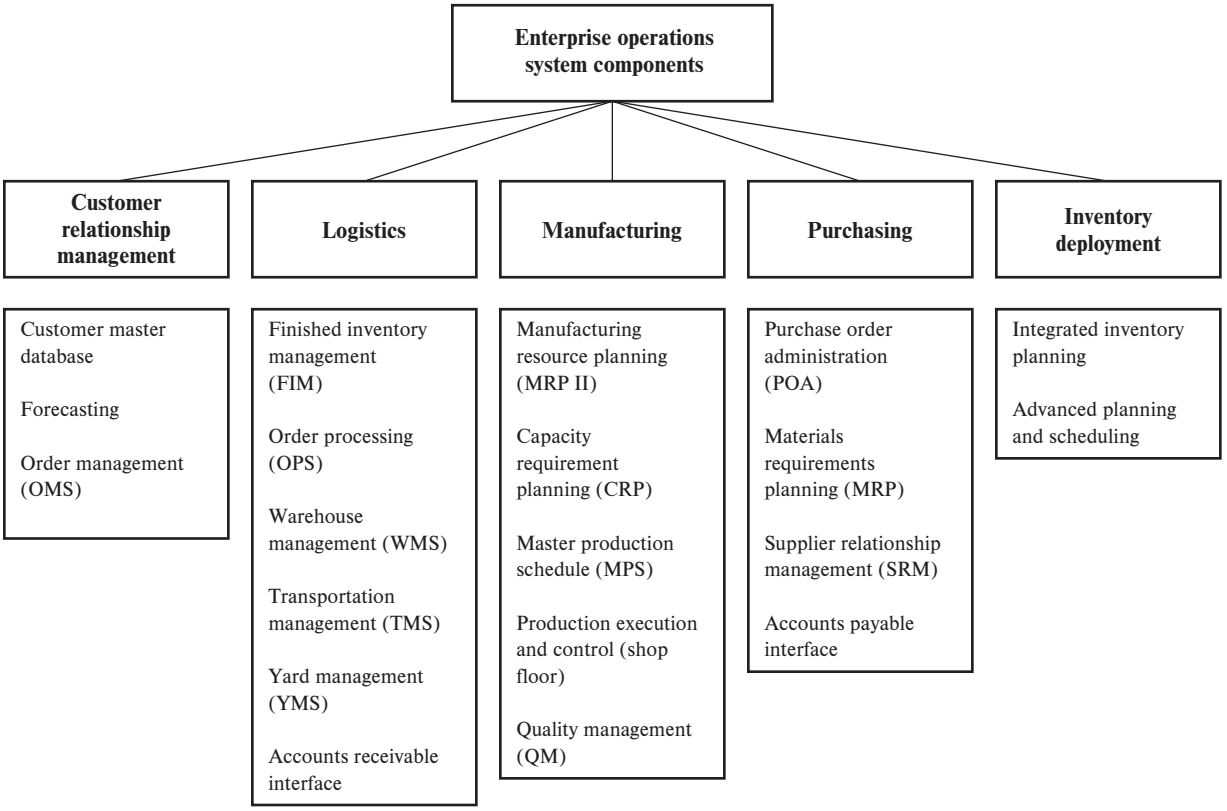


**FIGURE 2.5** Enterprise Operations Modules

production and deployment requirements. Typical operational applications included in each module are listed. These applications are discussed throughout the text in conjunction with operational topics.

The traditional information technology delivery method has been for firms to operate and maintain private computer capabilities. Large mainframe computer capacity is essential to operate the varied information technology systems necessary to guide supply chain operations. This commitment to internal computing has rapidly changed in the 21st century. Increasingly firms are purchasing supply chain information technology support in the form of externally hosted systems. These include cloud-based hardware and software. A wide variety of systems, such as **warehouse management (WMS)**, **transportation management (TMS)**, and **yard management (YMS)**, are available from technology application firms that specialize in providing and maintaining state-of-the-art performance systems. These applications are discussed briefly later in the chapter. Typically referred to as **Software as a Service (SaaS)**, these application-specific software packages can be purchased for either internal use or on a hosted basis. When hosted by specialized service firms that provide the application using the capabilities of large computer resources, the application is referred to as **cloud computing**.

## Enterprise Planning and Monitoring

Enterprise planning and monitoring are the processes and technologies that facilitate exchange of planning and coordinating information both within the firm and between supply chain partners. Figure 2.6 illustrates the major enterprise planning and monitoring

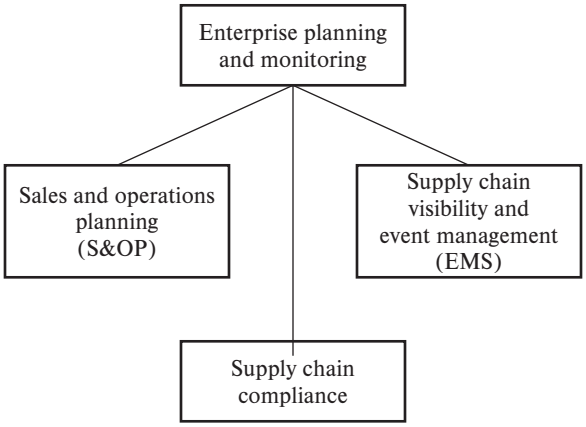


**FIGURE 2.6**
Enterprise Planning and Monitoring Modules

modules. The modules include (1) sales and operations planning, (2) supply chain visibility and event management, and (3) supply chain compliance. Since many of these activities involve interaction with other members of the supply chain, effective applications require substantial standardization with other firm functions and supply chain partners.

Sales and operations planning (S&OP), which is discussed further in Chapter 6, describes the process used to balance demand requirements and supply capabilities of the firm and its supply chain partners. While S&OP itself is a process requiring functional coordination and integration, it requires information technology to evaluate the demand, supply, and resource trade-offs. This technology is generally characterized as planning and scheduling applications. Supply chain visibility and event management tracks shipments while they are in-transit and are increasingly capable of proactively suggesting changes in supply chain flows to minimize the potential of manufacturing shutdowns or service failures. Supply chain compliance systems monitor component and product flow information to make sure they comply with government and regulatory requirements for label, taxation, and security restrictions.

## Communication Technology

Communication technology is the hardware and technical software that facilitates information exchange between the systems and physical infrastructure within the firm and between supply chain partners. The real-time information interchange between functions and supply chain partners facilitate coordination of inbound material, production, inventory, customer orders, and customer shipment. From a supply chain perspective, the availability of common and consistent requirements, activity, and performance information between supply chain partners enhances operational effectiveness, efficiency, relevancy, and sustainability.

## Consumer Connectivity

The rapid development and deployment of the Internet has added a new dimension to the interface between firms and their customers. Both retailers and manufacturers are increasingly in direct Internet contact with the end consumers. This connectivity has developed along two main dimensions of communication—ordering and after-sale connectivity. Each has supply chain implications.

In terms of ordering, the Internet offers a way for consumers to facilitate and maintain direct contact with retailers and manufacturers. In essence, this form of two-way connectivity is an expansion of traditional mail ordering. Empowered with the speed and flexibility of Internet connectivity, the interactive communications during ordering, determination of inventory status, processing time and location, and product delivery detail can be more diverse and comprehensive. For example, complete order-to-delivery tracking is a common feature. With the ease and speed of Internet connectivity, information concerning the total order to home delivery or retail pickup can be monitored.

With respect to product returns, or what is commonly called **reverse logistics**, the Internet offers a fast and accurate way to facilitate and track the product repair or replacement process. In addition, the existence of direct connectivity between the end consumer and the product manufacturer facilitates the rapid resolution of customer service issues related to product use and warranty.

In addition to information technology, the rapid emergence of supply chain relationships is being driven by four related forces: (1) integrated management and supply chain processes, (2) responsiveness, (3) financial sophistication, and (4) globalization. These forces will continue to drive supply chain structure and strategy initiatives across most industries for the foreseeable future. A brief discussion of each supply chain driver provides a foundation for understanding the challenges supply chain management places on exacting logistical performance.

## Blockchain

Blockchain is a communications technology that facilitates secure communication between financial and supply chain institutions. While the traditional mode for information between supply chain partners has been electronic data interchange (EDI), there has been increased concern regarding data accuracy, integrity, and security as information is exchanged between supply chain partners. This has been particularly true for situations involving sources of materials, tracking of production facilities, tracking of products through the distribution system, and global tracking.

While there are numerous industries that are challenged by counterfeiting, raw material falsification, and theft for resale, the firms that face the most significant challenges are those involved in high-value branded goods, repair parts for durable items, health care supplies, alcohol, and pharmaceuticals. In all cases, the combination of high value and the relative ease of counterfeiting in the eye of the consumer provides many opportunities for sale through gray market manufacturers and distributors. Since the packaging and the product often appear similar to the real product, counterfeiters sell the fake product at a premium price, which cheats both the consumer and the owner of the premium product brand.

The pharmaceutical industry is one of those most affected by counterfeiting. The combination of high value, relative ease of falsifying raw material, and use of gray market manufacturers and distributers makes counterfeiting very lucrative for the counterfeiters and very dangerous for consumers. The result is the passage of the Drug Supply Chain Security Act (DSCSA) in the United States and the passage of similar acts in many countries around the world. DSCSA requires that raw materials, finished goods, and packaging be tracked from the initiation of the manufacturing process through to the retailer or institution that transfers the product to the patient.

Blockchain is a distributed database that maintains digital contents regarding transactions or events that makes them tamper-resistant. While many institutions such as suppliers, manufacturers, distributers, retailers, and logistics service providers may access, inspect, or add to the data, they can't change or delete it. The original information is maintained in a permanent and public information trail, or chain of transactions.

Think of it like this: If the entire blockchain were the history of customer or replenishment orders, an individual order would be a single "block" in the chain. Unlike most supply chains, however, there is no single organization (supplier, manufacturer distributor, retailer, or logistics service provider) that controls these transactions. Once the "block" is loaded into the blockchain, it cannot be changed by any party, making it much easier and safer for the supply chain to monitor and track transactions across the Internet.

Blockchain technology allows firms to more securely and transparently track all product movement from manufacture to sale. The results are reduced time delays, added costs, and human error. There are an increasing number of supply chains that are using blockchain technology and it will likely become almost universal for products that are perishable or have expiration dates.

Specifically, blockchain technology can improve supply chain operations by:[1]

- Recording the quantity and transfer of assets—pallets, trailers, containers, etc.—as they move between supply chain nodes.
- Track purchase orders, change orders, receipts, shipment notification, or other trade-related documents.
- Assign or verify certifications or certain properties of physical products.
- Link physical goods to serial number, bar codes, and digital tags like RFID.
- Share information about the manufacturing process, assembly, delivery, and maintenance of products with suppliers and vendors.

Blockchain provides numerous benefits for supply chain operations, including:

- Enhanced transparency. Documenting a product's journey across the supply chain reveals its true origin and touchpoints, which increases trust and helps eliminate the biases found in today's opaque supply chains. Manufacturers making components can also reduce recalls by sharing logs with the assembly manufacturers and regulators.
- Greater scalability. Virtually any number of participants, accessing from any number of touchpoints, is possible.
- Better security. A shared, indelible ledger with codified rules could potentially eliminate the audits required by internal systems and processes.
- Increased innovation. Opportunities abound to create new, specialized uses for the technology resulting from the decentralized architecture.

## Logistics Operations Modules

Key elements of the logistics operations system components include (1) a transportation management system (TMS), (2) a warehouse management system (WMS), and (3) a yard management system (YMS). While these systems are discussed in more detail in the relevant functional chapters (Chapter 8 for TMS and Chapter 9 for WMS and YMS), the detail for each application is discussed briefly here to offer a perspective regarding how these components fit into the overall supply chain information system.

The TMS manages the transactions and resources related to the movement, analysis, and performance measurement of goods through the supply chain. The TMS system may be resident on the firm's computers but in most cases today, TMS services are accessible through an external service provider or cloud services to achieve economies of scale by

[1] Cottrill, Ken. "The Benefits of Blockchain: Fact or Wishful Thinking." Supply Chain Management Review (January/February 2018). pp 20–25.

sharing the applications across multiple users. The typical functionality offered by a TMS system includes (1) building loads from multiple orders, (2) identifying possible carriers, (3) maintaining database of shipment rates, (4) determining shipment mode and route, (5) providing documentation to select product to ship and stage it in the warehouse, (6) developing documentation for shipment, (7) tracking the order while it is in-transit between facilities, and (8) transferring shipment information to accounts receivable. The TMS application is discussed in more detail in Chapter 8.

The WMS manages and, in many cases, initiates the transactions that receive, store, retrieve, and ship product from the warehouse. The WMS may drive manual transactions or a sophisticated automated system. Unlike a TMS, which is often in a cloud environment that facilitates the sharing of transportation information between facilities and firms, the WMS is often decentralized with applications in each facility so that a failure in the communication between facilities will not force the warehouse to shut down. The typical functionality offered by a WMS system includes (1) shipment receipt; (2) product storage or put-away; (3) product retrieval from the storage location; (4) product staging for shipment; and (5) initiation of value-added activities such as packaging, labeling, or other forms of customization. The WMS application is discussed in more detail in Chapter 9.

The YMS manages the truck trailer or rail cars in the firm's yard or storage area. A major distribution center may have hundreds or even thousands of trucks in the yard waiting to be loaded or unloaded. In concept, the locations in the yard are similar to the pallet locations in the warehouse. When a distribution center needs an empty trailer to load for a shipment, the YMS directs the yard driver to a location with an empty trailer. In the case when the distribution center needs to access product that is in a trailer in the yard, the YMS indicates to the yard driver where the specific trailer is located and instructs the driver to bring the trailer for unloading. In essence, the YMS maintains the inventory of empty and full trailers in the yard and initiates transactions to move the trailers between the yard and the distribution center. The YMS application is discussed in more detail in Chapter 9.

## Summary

Supply chain information systems provide the backbone and nervous system for the modern supply chain. The enterprise resource planning system is the backbone as it includes the data warehouse and the capabilities to complete supply chain transactions such as order entry, inventory receipts, and shipping. Key requirements for the ERP system are data integrity, consistency, and transparency. The requirements for the transaction system are security, flexibility, and speed. While the ERP also provides accounting and human resources support, these are not technically a component of the supply chain information system. The supply chain operations contain the transaction capabilities to support customer relationship management, logistics, manufacturing, purchasing, and inventory deployment.

The enterprise planning and monitoring system provides the ability to complete manufacturing and inventory planning, which often requires trading off forecast accuracy, production cost, and inventory carrying cost. The monitoring system provides the ability to track inventory as it moves through the supply chain and offers visibility to events (weather, congestion, or other types of shipment delays) that may affect supply chain performance. Communication and blockchain capabilities facilitate the exchange and recording of order and inventory information across the entire supply chain.

## Study Questions

1. Discuss how supply chain information systems can provide a competitive advantage for the firm.
2. Compare and contrast supply chain transaction, management, decision analysis, and strategic planning systems.
3. Describe the benefits provided by blockchain technology.
4. Discuss the role of TMS, WMS, and YMS in supply chain execution.
5. Discuss the role of supply chain event management systems in supply chain competitiveness.

## Challenge Questions

1. Discuss how blockchain and tracking systems provide value to a firm's customers.
2. How do the concepts of SaaS and cloud computing differ from the services offered by traditional data processing service centers?
3. Compare and contrast a firm having its own information system, cloud computing, and SaaS.