A ROADMAP FOR THE SUPPLY CHAIN OPERATIONS REFERENCE MODEL (SCOR)

Karla Alvarado, University of Central Florida
Luis Rabelo, Ph.D., University of Central Florida

Abstract
The aim of this paper is to introduce a roadmap detailing how to apply the Supply Chain Operations Reference Model (SCOR) so that it can be utilized by service organizations to analyze, design, and improve supply chain performance. This roadmap arose out of lessons learned from a successful implementation of an aerospace company. We validated this roadmap by applying it in three different case studies provided by the Supply Chain Council (SCC). We then implemented this framework roadmap to streamline the service supply chain (using the Internet) of the government of Seminole County, Florida.

Introduction
This research work is inspired by lessons learned from a successful implementation of the Supply Chain Operations Reference Model (SCOR) at United Space Alliance, LLC and by the fact that SCOR has been mainly applied to manufacturing organizations around the world. SCOR offers an approach that can help companies to analyze, design, and improve supply chain performance. Its framework is both rigorous and flexible, allowing it to work in any industry and for any supply chain issue. One of the contributions of this investigation is to define a roadmap of how to apply the SCOR model in a service organization to improve its supply chain. Various concepts from different fields have been blended in order to achieve this objective.

A supply chain is the collection of independent business units or enterprises that temporarily work together as a unit to plan, design, produce, and deliver a product to satisfy an immediate or projected demand. The supply chain is a massive and complex collection of interdependent activities to satisfy this demand. The activities involved can include sourcing the rawest form of material to produce a product, manufacturing semi-finished parts and products, assembly, warehousing, ordering, distribution, inventory management, etc.

The evolution of supply chain management has not been linear over time. Various concepts and theories have been formulated to optimize supply chains to higher and higher degrees. The goals of supply chain systems are multidimensional and include cost minimization, increased levels of service, improved communication among partner companies, and increased flexibility in terms of delivery and response (Lancioni et al. 2000). Companies have concentrated on the development of individual modules of their supply chain starting with transportation component and then extending it to include warehousing, finished goods inventory, materials handling, packaging, customer service, purchasing, and finally, raw materials inventory.

In order to understand a supply chain and its complexities, we have to capture and model its structure. SCOR is a very effective tool for improving supply chains (Ayers 2004). Hence, SCOR and its tools have been utilized to understand the complexities behind a supply chain. SCOR is the product of the Supply Chain Council (SCC), an independent, not-for-profit, global corporation with membership open to all companies and organizations interested in applying and advancing the state of the art in supply chain management.

SCOR was introduced in 1996. It is a methodology for defining supply chains, measuring the size of the issues, and identifying necessary changes to improve performance. The strength of SCOR lies in its applications which transforms organizational behavior from event-driven reflexes to strategic, integrates team behaviors that put more focus on customers, helps the companies to achieve a core competency in solving supply chain problems, and achieves goals. SCOR philosophy is “if you can define your supply chain, which is not hard to do, then you can measure it,” and, “once you have measured it, you will find the opportunities are so big that you will not need any more motivation. You will want to drive continuous improvement in your supply chain” (Bolstorff and Rosenbaum, 2003); a supply chain is a continuous movement of information and material flows and should be studied holistically, and SCOR offers a step-by-step engineering approach that can help companies to analyze, design, and improve supply chain performance using reengineering, best practices analysis, and benchmarking.

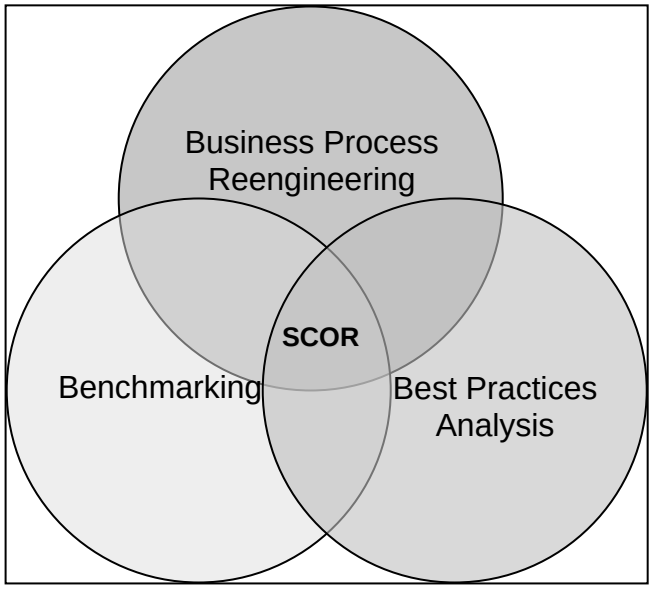
The central concept of the SCOR model is that all of the elements of a supply chain interact through causal relationships. This feedback system has to be analyzed correctly in order to predict the supply chain behavior through the studies of reengineering, best practices analysis, and benchmarking.

SCOR is a reference model that integrates three concepts in a single framework; these are business process reengineering, benchmarking, and analysis of best practices (as shown in Exhibit 1). This cross-functional framework makes SCOR unique and effective for complex management processes such as supply chains. The business process reengineering function captures the current or the "as is" status of the supply chain processes. The "as is" will clearly describe the current status of the supply chain and will serve as a starting point to optimize the supply chain processes and implement the "to be" supply chain. The benchmarking will quantify the operational performance of similar companies' supply chains, identify the best operating one, and establish its values as a target for the supply chain under consideration. The best practices analysis will determine the best means that will drive the "as is" supply chain to the desired target performance, i.e. the "to be" supply chain. The best means can include a management practice, a software solution, a new business model, new technology, etc. SCOR users will identify where they need to make improvement, the ultimate improvement they can attain, and how to achieve it. SCOR as a reference model links supply chain process with best practices, metrics, and technology.

SCOR (SCC, 2003) is structured around five supply chain management processes: Plan, Source, Make, Deliver, and Return, as shown in Exhibit 2. Plan processes balance available resources and aggregate demand, and they integrate different supply chain activities with supply chain partners' organizations. The result of the planning activity is an action plan to satisfy the aggregate demand. Source processes include sourcing the required materials, services, or any other outsourced activity. It is the link between the organization and the suppliers. Make processes are the collection processes that produce the final product. These processes apply only to some of the supply chain partners (e.g. manufacturers and assemblers). Deliver processes are concerned with orders and delivery of final products to the customer. It is the link between the organization and its customers. Return processes are the processes for returning products or materials to their source. The model Source, Make and Deliver process elements have four different structures for four product-business environment. The four different environments are Make-to-Stock, Make-to-Order, Engineer-to-Order, and Retail products.

By describing supply chains using these five processes, SCOR can be used to describe any supply chain at any level of details. This description can be used internally and externally across the enterprise, different locations, and industry sectors. This will allow enterprises to evaluate their supply chain processes' performance within their enterprise, suppliers, warehouses, or any other outsourced process.

Exhibit 1. SCOR and its relationships.



These five management processes are decomposed into the following three levels of detail:

Level 1-Top Level. Level 1 defines the scope and content at a strategic level. This the level at which the bases of competition performance targets are set. Under SCOR, supply chain management is defined as these integrated management processes: Plan, Source, Make, Deliver, and Return.

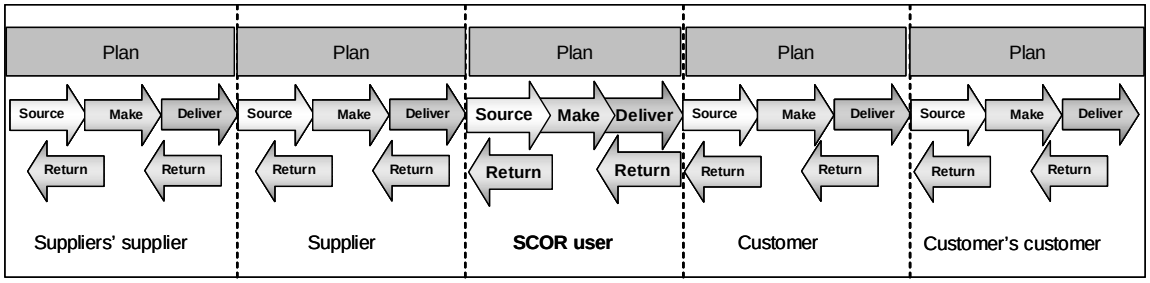
The Plan process assesses supply resources; aggregates and prioritizes demand requirements; plans inventory for distribution, production, and material requirements; and plans rough-cut capacity for all products and all channels.

The Source process obtains, receives, inspects, holds, issues, and authorizes payment for raw materials and purchased finished goods.

The Make process requests and receives material; manufactures and tests products; and packages, holds, and/or releases products.

The Deliver process executes order management processes; generates quotations; configures products; creates and maintains customer databases; maintains product/price databases; manages accounts receivable, credits, collections, and invoicing; executes warehouse processes including pick, pack, and configure; creates customer-specific packing/labeling; consolidates

Exhibit 2. SCOR five management processes on a multi-tier supply chain



orders; ships products; manages transportation processes and import/export; and verifies performance.

The Return process accounts for defectives, warranties, and excesses return processing, including authorization, scheduling, inspection, transfer, warranties administration, receiving and verifying defective products, disposition, and replacement.

2. Level 2-Configuration Level. A company's supply chain can be "configured-to-order" at Level 2 from the core "process categories." Companies implement their operations strategy through the configuration they choose for their supply chain. In this level SCOR defines the configuration of planning and execution processes in material flow, using standard categories like stock, to-order, and engineer-to-order.

3. Level 3 Process Element Level. Level 3 defines a company's ability to compete successfully in its chosen markets. Also, this level defines the business process used to execute sales, purchase, replenishment, work orders, return authorizations, and forecasts. This is the level at which companies improve their operations strategy, and it consists of:

- Process element definitions
- Process element information inputs and outputs
- Process performance metrics
- Best practices
- System capabilities
- Systems/tools

Also, SCOR Model describes supply chains using five criteria: reliability, responsiveness, flexibility, cost, and asset management. These criteria are used by SCOR as performance attributes to evaluate supply chains and for comparing different supply chains. SCOR also defines metrics, to be the guide for calculations by which the company can measure their supply chain performance and compare it to others. Like the process elements, metrics in the Model are hierarchical.. Level 1 Metrics are derived from lower level calculations. (Level 1 Metrics are primary, high level measures that may cross multiple SCOR processes.) Lower level metrics (e.g. Level 2 metrics) will be derived in the same manner but for a sub-process, and so on. The performance attributes and the associated Level 1 metrics are shown in Exhibit 3.

Supply chain performance attribute	**Metric**
Reliability	Delivery Performance
	Fill Rates
	Perfect Order Fulfillment
Responsiveness	Order Fulfillment Lead Times
Flexibility	Supply Chain Response Time
	Production Flexibility
Costs	Cost of Goods Sold
	Total Supply Chain Management Costs
	Value-Added Productivity
	Warranty / Returns Processing Costs
Asset Management	Cash-to-Cash Cycle Time
	Inventory Days of Supply
	Asset Turns

Exhibit 3. Supply Chain Attributes and Metrics.

SCOR Methodology - How to Apply

This investigation has found that the SCOR methodology has been mostly used for modeling the supply chain of manufacturing organizations. SCOR has provided a framework in order to understand the complexities underlying the supply chain structure of an organization. Surveying the research work done in this field provided us with an opportunity to understand its applications.

This review reveals that there is a need for development of a roadmap of how to apply the SCOR model in any organization and offer a step-by-step engineering approach that can help organizations to

analyze, design, and improve supply chain performance (as shown in Exhibit 3). This work intends to fill this gap by developing a roadmap, which will be able to apply this model in supply chains.

United Space Alliance (LLC) is the primary contractor for NASA's Space Shuttle Program under the Space Flight Operations Contract (SFOC). The organization's headquarters are located in Houston, Texas, but its employees are spread all over the country, in places such as Florida, Alabama, Texas, California, and Washington D.C. The organization's mission is to conduct work involving multi-purpose space systems in NASA's human space flight program and operate and maintain the Space Shuttle fleet covering a broad range of responsibilities.

Through face-to-face meetings, interviews, and understanding situations experienced by United Space Alliance during their SCOR implementation, we developed a roadmap of how to apply the SCOR model (see Exhibits 4a and 4b). We verified the roadmap, applying it in three different case studies – Siemens, CISCO, and IBM – and we validated it through applying it in a government agency, Seminole County, located in Florida. The phases of the SCOR roadmap are detailed as follows:

1. Educate for support
2. Discover the opportunity
3. Analyze the strategy
4. Design the solutions
5. Develop the directions
6. Implementation

Phase I involves educating the organization in order to get support from every single employee. This phase includes some interviews, measure of work time, walk-throughs, questionnaires, brainstorm sessions, workshops, team formation, and management briefings.

Phase II involves discovering the opportunity in order to improve the current supply chain. Discovery helps to form the business case that justifies spending money on a supply chain project. In this phase the company is going to discover (1) at what level the supply chain is operating, (2) if they have the right strategy as well as the right work, information, and material flows to support the performance level, and (3) the other performance factors that will impact the supply chain. This phase includes checklists, interviews, and the project chapter which organizes the supply chain opportunity into the approach, budget, organization, clear measures of successes, and communication plan. This is where the mapping of the "as is" of the current process begins.

Phase III consists of the analysis stage to develop the strategy. In this phase, SCOR helps the team to prioritize and balance customer metrics with internal-facing metrics: delivery, reliability, flexibility/responsiveness, cost, and assets. The resulting SCORcard provides a direct connection to the balance sheet. Performance requirements are established with respect to the company and are prioritized by both definitions of a supply chain, product and channel. These priorities will help in Phase IV of a SCOR project. The SCORcard also summarizes actual performance against benchmark performance with a gap analysis that defines the value of improvement.

Phase IV consists in the design of solutions. This phase is divided into material flow and work and information flow which are the key components for defining "As Is" flows, uncovering disconnects in the process. Also, this phase provides solutions to important questions: What are the material flow problems and what's it worth to solve them? How efficient is the work and information flow and what's it worth to change them?.

Phase V consist of developing the direction to the new "to be system." This phase follows industry standard practices of initiating, planning, executing, and formal closing. Also, this phase provides the in-depth review of proposed changes; defines the desired state for both information and material flow; prioritizes the process changes; and validates the necessity of changes with the team.

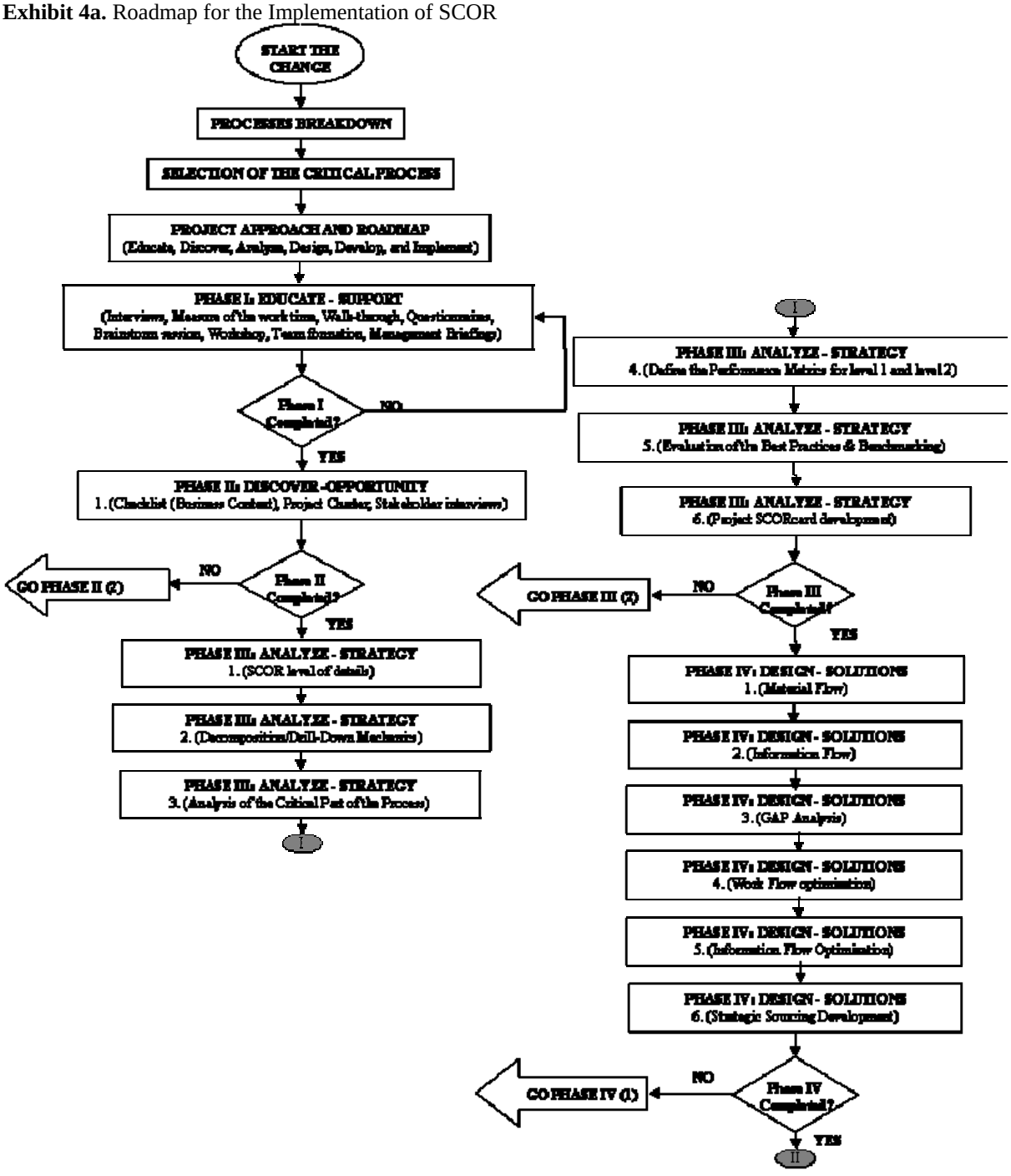
Phase VI consist of the implementation of the desired system. In this phase, SCOR helps the company to prioritize supply chain changes, to validate the opportunity analysis, to schedule the implementation, to develop the supply chain project continuous improvement plan, to detail the design, and to select the technology needed.

Verfication

This roadmap was verified in three different cases – Siemens, CISCO, and IBM (provided by the SCC). We made some modifications to the developed SCOR step-by-step engineering.

Siemens had implemented SCOR throughout its entire enterprise. The implementation of this process reference model supported the company's move to e-business. This case reviews strategies, opportunities, and challenges of implementing digital business communications. Vision, mission, and value proposition, as well as specific goals and milestones of Siemens as

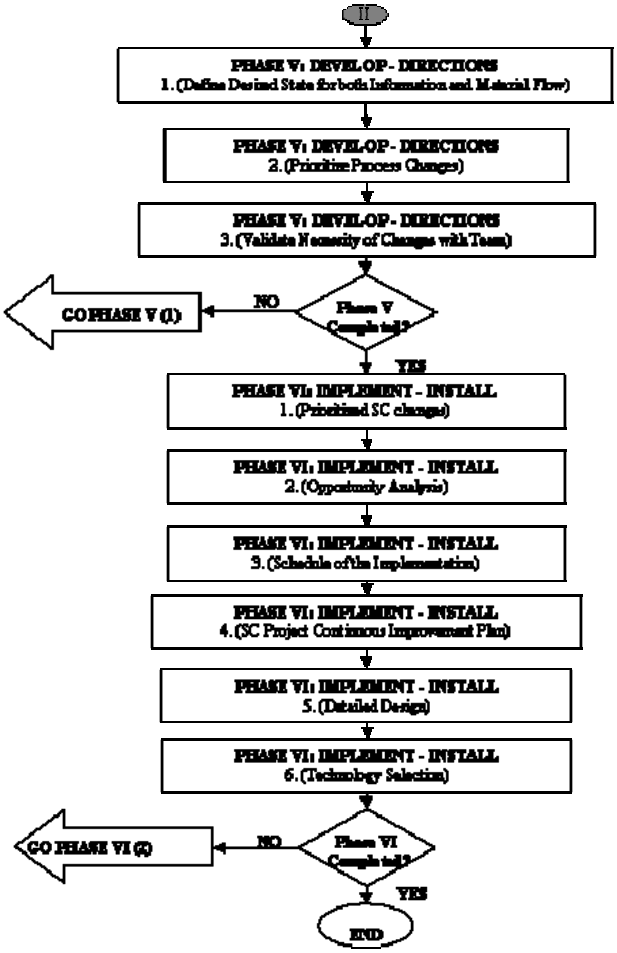
Exhibit 4a. Roadmap for the Implementation of SCOR



an integral part of its trading partner networks, upstream and down, are focused on a breakthrough in its overall competitiveness in the context of e-business. The roadmap developed was able to model the steps taken by Siemens to implement SCOR.

Also, the impact of e-business on the supply chain has been a big challenge for CISCO. The SCOR model provides the right tools to better manage their supply chain in order to improve their business communication. Again, the step by step roadmap was able to contribute to the understanding of the process followed by CISCO.

Exhibit 4b. Roadmap for the Implementation of SCOR (continued)



The IBM case study verifies the SCOR model in the fast moving consumer goods/high technology industry, and it shows how technology supports SCOR. The SCOR model can demonstrate how SRM can be used to collaborate with supply chain partners, how technology supports effective SRM, and how SCOR is applied with fast moving consumer goods industries (IKEA, Sainsbury, Kodak, technology company). The roadmap developed was able to describe the processes followed by IBM.

The Seminole County Planning and Development Department Case Study

The roadmap developed was validated with a service organization: Seminole County, which is located in Sanford, Florida. Seminole County is one of the fastest growing counties in the United States, and its population is expected to increase by 20% over the next twenty years. The expected growth brings customer service challenges to Seminole County, both internally and externally. The Seminole County Planning and Development Department (SCPDD) has the goal to exceed customers' expectations. The SCPDD evaluated its current organization and used the SCOR model in an effort to implement changes that will automate and integrate the department's planning and development related processes and services using the Internet. The overall goal was to revamp the Department, making the best use of the SCOR model to define, measure, and improve their supply chain and facilitate the implementation of "e-Government."

SCPDD is in charge of nine processes. Those processes have their own way to do business. Those processes are:

1) Agenda Review Process
2) Planning and Zoning
3) Addressing Process
4) Building Process
5) Land File / Property Appraiser
6) Development Review Process
7) Community Development Process
8) Cash Receipts
9) Impact Fees Utility Billing

After several face-to-face meetings, interviews and walk-throughs, we decided to select as a critical process the Agenda Review Process. We divided the Agenda Review Process in three phases. Phase I describes the process that the external customers have to follow in order to submit their application to a specific department, which will review it and prepare it for the Agenda Review Process. Phase II involves the Agenda Review Process, whih is defined as a continuous process that an item has to follow in order to be reviewed by the Board of County Commissioners (BCC). Phase III involves the process that an approved or denied item has to follow after the BCC public hearing.

Application of the roadmap for Seminole County has the following structure as depicted in Exhibit 5.

Phase I: Educate to Support. SCOR, as an industry standard, makes the sell easier because it has gained credibility from a long list of successful case studies. But the model cannot sell itself, and it cannot teach people who are not ready to learn. That's what this Phase I is for; any SCOR project will depend on three key roles in the education process. These are the evangelist, an active executive sponsor, and the core members of an executive steering team. Without these, any organization cannot hope for the project's success.

Exhibit 5. Project Approach and Roadmap.

Educate to Support	Discover the Opportunities	Analyze the Strategy	Design the Solutions	Develop the Directions	Implement the Change
Interviews Measure of the work time Walk-through Questionnaire Brainstorm session Workshop Team formation Management briefings	Checklist Project Charter Stakeholder interviews "As-Is" process flow	SCOR level of detail Decomposition/ Drill-Down mechanics Define critical part of the process Define the performance metrics for level 1 and level 2 Evaluation of the Best Practices & Benchmarking Project SCORcard development	Material flow Information flow GAP analysis Work flow optimization Information flow optimization Strategic sourcing development	In-depth review of proposed changes Define desired state for both information and material flow Prioritize process changes Validate necessity of changes with team	Prioritized SC changes Opportunity Analysis Schedule of the implementation SC project continuous improvement plan Detailed design Technology selection
1 Month	**1 Month**	**1 Month**	**1 Month**	**1 Month**	**3 Months- Ongoing**

At Seminole County we interviewed executives who have experienced the power of process improvement and understand the key roles in process management, managers who have invested personal time learning about the strategic value of supply chain, and workers who have the day-by-day experience and make the customer service possible. People who understand the process (stakeholders) were interviewed. In addition, the process included reviews of the existing documentation. Flowcharts to document information from interviews, including time for steps and information flow, were developed. Simultaneously review documentation with stakeholders took place.

Phase II: Discover the Opportunity. There are three primary deliverables for this phase. They are the business context summary, a supply chain definition matrix, and an approved project charter.

For the business context, we started with a checklist, which outlines information needed to be reviewed and summarized to gain a full understanding of the business context for the supply chain improvement. This sets the direction for supply chain focus.

The project charter is created to establish a complete understanding of the project's scope and objectives. This document helps to align assumptions and expectations among stakeholders, team members, and sponsors. The components of the project charter are: scope, business and project objectives, methodology, schedule, deliverables, risks and dependencies, budget, organization chart, roles and responsibilities, stakeholder expectations, benchmarks, benefit analysis, critical success factors, communication plan, and control procedure.

The stakeholder interviews are part of the business context and they are the key to reviewing and summarizing the business process.

Once we understand the project's scope and objectives, we start collecting information about the

"As-Is" process flow, both material and information flows, in order to start mapping the current Agenda Review Process supply chain.

Phase III: Analyze the Strategy. The supply chain has to be defined, identifying suppliers, customers, the suppliers of the suppliers, and the customers of the customers. In the Agenda Review Process the suppliers consist of the internal departments (Building Permit, Community Resources, Development Review, and Planning and Zoning) that provide the Agenda Item package. When the Agenda item package is submitted, it is then eligible to be reviewed, approved, and forwarded to the BCC public hearing. The internal departments are supplied by the external applicants. The external applicants are made up off current and potential Seminole County community residents/businesses.

In the Agenda Review Process the customers are the internal departments (Building Permit, Community Resources, Development Review, and Planning and Zoning) that are going to take the reviewed and approved Agenda Item package to the BCC public hearing. The internal departments then deliver the Agenda item package to the BCC public hearing, where each department presents and reviews each Agenda item with the board.

After we specify the Agenda Review Process SCOR Level 1 of detail, which is related to the strategic level (process types), we need to work on the Decomposition mechanics in order to determine the current state of the supply chain (process categories), which is SCOR Level 2 of detail, and the "As-Is" state (decompose processes) to design the desired state (process elements), which is Level 3 of detail .

In addition, the following is performed during this phase:

1. Definition of the Performance Metrics for Level 1 and 2
2. Evaluation of the Best Practices & Benchmarking
3. Development of the project SCORcard

Phase IV: Design the Solution. The fourth phase of the project life cycle focuses on supply chain design – the effort to identify organizational, process, personnel, and technology changes to close metric gaps calculated in the SCORcard. First we focus on physical material flow. Primary deliverables are "As-Is" material flow, disconnect and gross opportunity analysis, material flow strategy and appropriate leading practices, and "to be" material flow. Second, we align practices and look at processes and systems involving work and information flow. Primary deliverables are "As Is" work and information flow, transactional analysis, "to be" work and information flow, and productivity impact summary.

At the conclusion of the design phase, we combine, value, and prioritize changes in material, work, and information flow.

Phase V: Develop the Directions. In-depth reviews of the proposed changes concluded that Seminole County needed a new process that can initiate the integration in order to satisfy customer needs. Research into software solutions has provided one other alternative, which provides agenda and legislative tracking. This new process needed to be able to:

- Integrate with other systems
- Simplify the development life cycle
- Provide in-house and vendor support
- Define desired state for both information and material flow
- Prioritize process changes and validate necessity of changes with the team

Phase VI: Implementation. In order to guideline the Agenda Review Process supply chain changes, we designed a table that includes elements that can characterize the issue and root cause analyses, recommended changes, action plans, and responsibility (Exhibit 7).

The implementation phase includes the following:

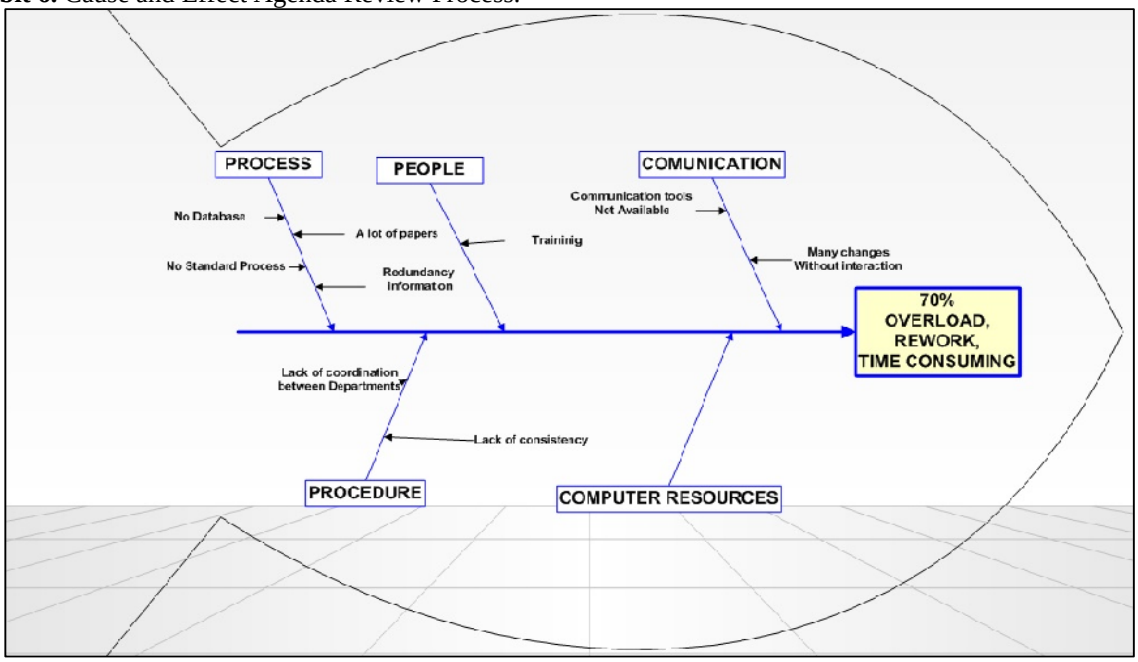
- Opportunity analysis
- Schedule of the amplementation
- Supply chain project continuous improvement plan
- Detailed design
- Technology selection

Results. The roadmap helped to implement SCOR successfully in Seminole county. SCOR supported the development and selection of a software system being implemented at Seminole County. Several subprocesses have been streamlined, and lead times have been reduced by approximately 35%.

SCOR Alternatives

SCOR could be tied to Value Stream Mapping. Value Stream Mapping was developed by Toyota and later adapted as Value Stream Mapping by James Womack, and consists of all actions, both value-creating and wasteful, required to bring a product from raw material into the arms of the customer. It is based on the material and information flow (MIF) maps. This methodology can help to find both the waste and the

Exhibit 6. Cause and Effect Agenda Review Process.



flow of value highly visible to everyone. Companies can benefit from Value Stream Mapping in situations such as: diagnostic for functions and for the relations between firms; understanding of product cost, having a clear picture of the manufacturing processes; reducing the work in process (WIP) and the production lead time; responding to demand changes and to quality concerns; increasing the value added contribution; and standardizing the production process.

Lean and Six Sigma can provide SCOR with the infrastructure and the execution mechanism to make good SCOR-based Supply Chain process design a reality. The top-to-bottom organization impact of a Lean and Six Sigma program can be extended to include SCOR so that awareness and application of the model is threaded throughout the entire company. The program infrastructure, roles and responsibilities, training and development capability, and execution oriented tools of Lean and Six Sigma are ideal for taking the output of SCOR.

We would like to say that some of these approaches have many similarities (and the philosophy and some of the processes are actually the same). They can be complemented to develop new paradigms – however, there are significant redundancies to be explored in future investigations.

Conclusion

SCOR is a managerial tool to define supply chains, measure the size of the issues, and identify necessary integrated team behaviors that put more focus on customers. This work provides a roadmap for applying the SCOR model.

In addition, this work provides a good framework of how companies can implement e-supply chain strategies. Companies can improve their supply chain operations through sharing of relevant information and perfecting demand and supply processes by using Web technologies. We are exploring ways to improve the SCOR model using another tools such as Lean Manufacturing and Six Sigma. Six Sigma can provide SCOR with the infrastructure and the execution mechanism to make good SCOR-based Supply Chain process design a reality. The top-to-bottom organizational impact of a Lean Six Sigma program can be extended to include SCOR so that awareness and application of the model is threaded throughout the

Exhibit 7. Agenda Review Process' Guideline Project Table

PACE OF CHANGE			
SCOPE OF CHANGE		FAST	MEASURED
	TACTICAL	Focused Improvement	Continuous Improvement
	STRATEGIC	Focused Restructuring	Business Process Innovation

entire company. The program infrastructure, roles and responsibilities, training and development capability, and execution oriented tools of Lean Six Sigma are ideal for taking the output of SCOR.

References

Ayers, James B. *Supply Chain Project Management: A structured collaborative and measurable approach*, (2004).

Bolstroff, P. and R. Rosenbaum. *Supply Chain Excellent. A handbook for dramatic improvement using the SCOR model*, (2003).

Lancioni, R., Smith, M. F., and Oliva, T. A.,"The role of internet in supply chain management", *Industrial Marketing Managemen*t, 29, (2000).

Supply Chain Council (SCC), *Supply-Chain Operations Reference (SCOR) Model V.6.0*, (2003).

Supply Chain Council (SCC), *Supply Chain Council*, www.supply-chain.org, (2004).

About the Author(s)

Karla Alvarado received her M.S. degree from The University of Central Florida in Industrial Engineering and Management Systems. She holds a B.S. degree in Industrial Engineering from UNEXPO University in Venezuela. Her research interests include supply chain management, simulation/modeling, and quality assurance.

Luis Rabelo is an Associate Professor in the Department of Industrial Engineering and Management Systems at the University of Central Florida and a NASA Fellow. He holds M.S degrees in Electrical Engineering (Florida Institute of Technology), Systems Engineering and Management (Massachusetts Institute of Technology), and Engineering Management (University of Missouri-Rolla), and a Ph. D. in Engineering Management from the University of Missouri-Rolla. He has also been a Senior R&D Engineer and Program Manager for the Advanced Technology Group of BF Goodrich and a Lead Scientist and Program Manager in the Honeywell Technology Center. His research has received grant funding from NSF, NASA, NIST, DOE, ONR, and private industry. He has over 120 publications, 8 invention reports, and three international patents in the areas of signal processing, artificial intelligence, neural networks, and optimization.