CHAPTER ONE

INTRODUCTION

A few years ago I conducted a workshop for the operating committee of one of the world's largest industrial conglomerates. The head of operations for each business unit plus the company's chief operating officer (COO) participated. We had a question-and-answer session at the end of the workshop. The COO asked the first question: "Dr. Frazelle, we have quite a bit of conflict in these meetings, especially lately. Why is that?" I asked him what the charter of the group was. He said, "We have two main objectives. The first is to reduce inventory. The second is to lower our unit costs." I said politely, "You just answered your own question. Your main methods of reducing unit cost—global sourcing from cheap labor sources and buying in large quantities to receive discounts—increase your inventory levels. Your objectives are at odds with each other, so you are at odds with each other." He asked me what they should do about it. I encouraged them, as I encourage all our clients, to take a step back and reconsider their objectives and their approach. I suggested that their objectives would preferably be to maximize return on invested capital

(ROIC), improve the perfect order percentage, spend whatever was required in total supply chain cost to support those objectives, and invest in whatever inventory level was required to accomplish those objectives. Sometimes that inventory level will be higher, and sometimes it will be lower. *Inventory is not an end in itself; it is a means to an end.*

We encounter this conflict in nearly every client situation. In all but the wisest and most mature organizations, highly qualified professionals are required to do the impossible: respond to a barrage of typically uncoordinated and irreconcilable initiatives from across the organization. Those initiatives normally include many of the following: increase stock keeping units (SKUs), increase customization, increase inventory availability, reduce customer response times, reduce transportation costs, reduce purchase costs through global sourcing, reduce manufacturing costs, and mitigate increasing supply chain risk with multiple sources. All of these initiatives naturally work to increase inventory levels. Yet in a prevailing context of lean thinking, most supply chain professionals are still required to reduce inventory.

A few months ago the head of logistics at one of the world's leading computing industry companies called in tears over the impossible situation in which they had been placed. That was a first: inventory angst to the point of tears.

1.1 WHAT'S THE PROBLEM?

The inventory conundrum is exacerbated by at least five complicating factors:

- Data discrepancies
- Inadequate training and education
- Problematic perspectives
- Misaligned metrics
- Poisonous paradigms

DATA DISCREPANCIES

1. *Base data errors.* In many companies the base data used to control and plan inventory and support inventory decision making is *just plain wrong*. In a recent project with one of the world's most prominent heating, ventilating, and air conditioning (HVAC) firms we discovered that more than 50% of the material requirements planning (MRP), bill of materials (BOM), and on-hand inventory records were wrong. In a recent engagement with a large engine manufacturer we found that inventory planners were regularly manipulating historical demand, set points, and parameters to falsify turn rates.
2. *Unvetted changes.* It is not unusual to find hundreds of people, qualified and unqualified, with and without accountability, making unvetted changes to schedules, demand, supplier data, and MRP data. We recently came across a client situation in which more than 500 people had the ability to make changes to multi-million-dollar assembly schedules. With a large retailer we found that more than 300 people had clearance to modify multi-million-dollar store order replenishment schemes.

INADEQUATE TRAINING AND EDUCATION

3. *Untrained planners.* On the basis of my experience, I estimate that fewer than 30% of inventory planners and analysts working with inventory systems have any formal education in inventory management. During a recent project I asked to see the résumés of the inventory planners. Fewer than 10% had received formal training in the decisions they were making. Many people pulling inventory triggers don't know how to use the gun.
4. *Faulty fundamentals.* Because so few inventory planners and managers have inventory training and education, there is *widespread misunderstanding and misapplication of inventory*

management fundamentals. During a recent engagement with a large healthcare company I asked about inventory accuracy. They said that it was well above 98%. I was suspicious, and so I asked them how they defined inventory accuracy. They said it was the portion of demand shipped from inventory. I explained that that was the fill rate, not inventory accuracy. I then asked what their inventory accuracy was. They didn't know.

PROBLEMATIC PERSPECTIVES

5. *Conflicting perspectives*. Every inventory decision affects financial, service, and operational performance. However, very few individuals understand all three and very few decision support tools consider all three. As a result, different inventory levels appear high or low depending on the lens you are looking through. Those views need to be reconciled; that is a major point and objective of this book.
6. *Irreconcilable interdependencies.* Decisions made in customer service, inventory management, manufacturing, sourcing, transportation, and warehousing all work interdependently to affect inventory levels. However, very few individuals understand those interdependencies and very few decision support tools consider them.
7. *Operations myopia.* Inventory is typically viewed as an operational or tactical outcome. It is rarely viewed as a strategic contributor to an overall supply chain strategy that in turn serves as part of an integrated business strategy.
8. *Misplaced accountability***.** Many people *influence* inventory levels, but often no one is *accountable*. I like to ask our clients early on who is accountable for inventory. The answer is revealing and quickly highlights the organizational and measurement root of inventory and/or supply chain issues.

9. *No microscopes.* Every SKU has a unique demand pattern, supply pattern, and dimensional profile. Individual SKUs are bought, sold, and slotted. Yet most companies resist individual SKU inventory optimization and planning. Even in cases with 100,000+ SKUs we have developed individual SKU strategies and rolled them up into category and business unit inventory strategies. Inventory strategy is a top-down *and* bottom-up endeavor. Wide-angle lenses *and* microscopes are required and available.

MISALIGNED METRICS

10. *Traditional accounting.* Traditional accounting treats inventory strictly as an asset, whereas operationally and philosophically inventory is popularly considered a liability. The truth is that the right inventory is an asset and the wrong inventory is a liability.
11. *Conflicting metrics*. Metrics used in the five supply chain logistics activities—customer service, inventory management, sourcing, transportation, and warehousing—often work at odds with one another and yield excess inventory.

POISONOUS PARADIGMS

12. *Procurement "cost avoidance."* In the name of cost avoidance, procurement is still looking for the cheapest first price even though it may cost much more in related excess inventory carrying costs.
13. *Lean.* Lean literature and previously idolized supply chain operators often veil the fact that their inventory turn advantages typically come at the expense of suppliers farther up the chain.

Were it not for poor fundamentals, grasping for silver bullets, limited education, misaligned metrics, myopic perspectives, misplaced influence

and accountability, misalignment with corporate strategy, and false prevailing paradigms, developing inventory strategy would be a piece of cake.

During a recent client workshop the chief supply chain officer noticed that I was becoming discouraged as they bemoaned their inventory ills. He said, "Dr. Frazelle, don't get discouraged. We don't. We just keep our heads down, keep making stuff, and hope it turns out okay in the end." Fortunately, he was joking. Unfortunately, many people live in the world keeping their heads down, making and buying stuff, and hoping it turns out okay in the end. There has to be a better way.

1.2 MORE OR LESS

There are myriad interdependencies and complexities in inventory decision making. The complexity overwhelms and discourages many people. They often give up and assume, based on the prevailing winds of trade literature and stock analyst exhortations, that less is better. Sometimes they are right. Sometimes they are wrong.

Lean thinking is so ingrained and influential that adding inventory is considered almost criminal, as if there were an inventory police force lurking around every decision to catch someone adding inventory to a supply chain. Yet in several of the supply chain strategies we have recently completed the answer was to increase inventory levels, and in each case this led to improved financial, service, and operational performance.

In a recent project with one of the most successful consumer products companies in the world, well known for its inventory management, we found that financial metrics for inventory performance were not in place. When we used our RightStock™ financial metrics in combination with our service and operational metrics, we found that the company was underinvested in inventory. Increasing its inventory investments helped the company gain significant market share, increase customer satisfaction, raise profits, and increase share price.

In a recent project with a large bottler we found that because of lean leanings and a proliferating SKU base, the company was running lot sizes half the size of optimal. Increasing lot sizes and related warehousing space led to significant reductions in total supply chain costs.

We are currently working with a large aerospace company on its supply chain strategy. The strategy revolves around one of the world's most advanced engine assembly facilities. After touring the facility I was asked what I thought about it. I shared my concern that the facility had been built under an assumption of a nearly guaranteed steady cadence of supply and demand that in light of global and competitive dynamics was unreasonable. It appears that a greater inventory investment will be required to operate that supply chain.

A few years ago we worked with a large provider of financial services software and terminals. The annual revenue related to each terminal dwarfs the annual inventory investment required to keep each terminal operating. Despite previous attempts to lean out the inventory, we found that the inventory strategy required a much larger number of relatively inexpensive keyboards, terminals, and cables to guarantee that terminal downtime affecting multi-million-dollar and sometimes multi-billion-dollar decisions was not an issue.

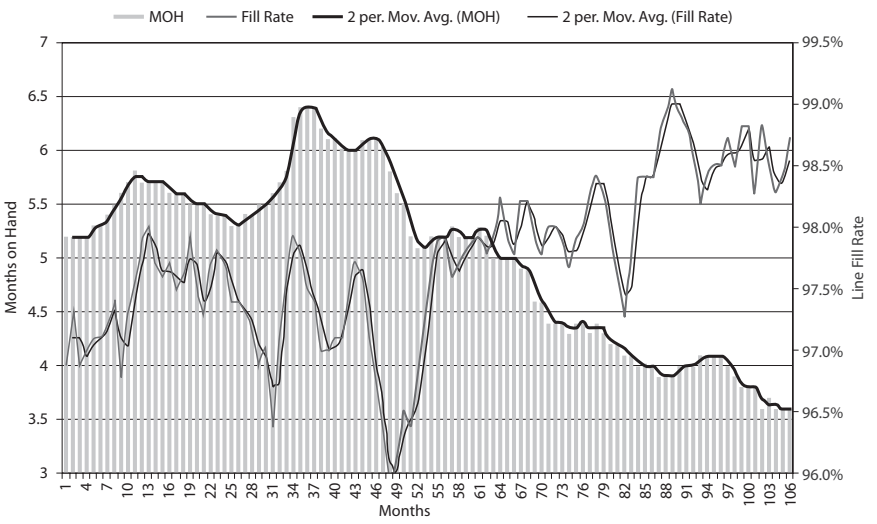
I could keep going, but you get the picture. Sometimes the answer is more inventory. Sometimes the answer is less.

HONDA

We have been fortunate to work with Honda for many years. Our work with that company began when Jim Roach, its head of sales and service, attended one of our supply chain strategy seminars. I was curious why such a high-level executive was at our seminar. He explained that he had complained so much about the performance of Honda's supply chain that the company president finally assigned it to him. To his credit he invested himself and his team in learning and implementing the RightChain™ and RightStock models.

After a year of intense work in SKU rationalization; customer service optimization; forecasting improvements; dramatic lead time reductions, including daily delivery programs to dealerships nationwide and weekly delivery programs from suppliers worldwide; and significant process and warehouse management system (WMS) improvements in its nine distribution centers (DCs), a success story was born. That story is illustrated in Figure 1.1. Historically, when there was a downturn in service, inventory levels were simply raised to close the gap with target fill rates. When inventory levels were deemed too high, they were systematically reduced, creating unacceptably low fill rates. That cycle went on, as it does in many companies, for many years. Once the RightStock model kicked in, inventory levels were cut in half from six months on hand to three months on hand. Fill rates increased dramatically as well, growing from a low of 96% to a high of 99%. The business results included reducing inventory investments by tens of millions of dollars, increasing profitability to the point where that business unit became the most profitable at Honda, and improving service to the point at which Honda led in all industry-related service categories.

Figure 1.1 Honda's RightStock Journey: From Worst to First



HALLMARK

Our work with Hallmark began with a call asking for assistance in locating a new distribution center. We asked why they needed the new distribution center. They said that inventory levels had grown to the point where they had exceeded the network's storage capacity. We asked them why their inventory was growing so quickly. They told us that they had been increasing their SKUs in hopes of increasing sales but that sales had remained flat. When we revealed to them the reduction in return on invested capital and shareholder value related to the potential DC, they took a step back. To make a long RightSKUs™ story short, after optimizing the SKU base and related inventories, we determined that they needed only about 60% of their existing inventory and related storage space. That led to the closing of two major DCs. In a strange twist of inventory fate, one of those DCs was acquired by our bottling client, which needed to increase its inventory levels in that locale (Figure 1.2).

Depending on many factors and interdependencies, sometimes less inventory is needed, and sometimes more. Sometimes the answer is the same

Figure 1.2 Sometimes More and Sometimes Less
This 233,000-square-foot DC in Raleigh, North Carolina, was vacated by Hallmark and acquired by Coca-Cola Consolidated.

inventory invested differently. Sometimes the answer is different inventory. Sometimes the answer is the same inventory relocated. The only way I have ever been able to figure it out is to *run the numbers.*

Recently we worked with a large food company on its supply chain and inventory strategy. One of the project team meetings was unusually quiet. The COO pulled me aside after the meeting to talk about the team's participation. He told me that one of the team members had told him that the group members had become reluctant to speak up because they assumed I always knew the answer to whatever inventory question was on the table. I shared with him and with the group that I rarely know the answer before we start a project. There are too many interrelated factors to know philosophically or in advance of putting the numbers to the scenario. What I do know is how to figure out what to do. We call that optimization.

1.3 OPTIMIZATION

Optimization is a facet of our RightStock program that differentiates it from operational, quality, and/or philosophical approaches to inventory management. Those approaches include lean, Six Sigma, pull, and just in time (JIT). Those approaches all have their roots in the Toyota Production System and implicitly assume that inventory is waste, that perfect quality is always the goal, and that moving things between places more often is always better than carrying inventory.

Through optimization, we take into consideration the unique economic and competitive climate, financial goals, customer service requirements, logistics conditions, and culture of each business to help determine the right supply chain and inventory strategy. Though it may sound heretical, *optimal strategies may require carrying more inventory.* That was the case in four of our largest and most successful supply chain strategy engagements in a recent year. In each case, the strategic increase in inventory led to higher profits, higher market share, and higher levels of customer

satisfaction. Though it may sound counterintuitive, the optimal solution may not mean perfect quality but optimal quality. We use a computation of the cost (expense, capital, and lost revenue) of poor quality to help our clients determine the optimal level of quality and appropriate investments in quality improvements. Though it may sound heretical, optimal supply chain strategies may involve fewer, less frequent movements using less expensive transportation modes. It is the cost of fuel and freight relative to the cost of carrying inventory and the customer service requirement that should determine the frequency, length, and modes for supply chain moves, not the philosophical or operational paradigms of supply chain mantras.

Our RightStock model employs optimization as the basis for decision support. Optimization is a formal, data-driven decision support approach. It decomposes a decision into an objective function and constraints and conquers it with a logical algorithm or heuristic. I have found it to be one of the most effective and reliable means of problem solving and decision support. I have also found that the concept escapes many professionals in our seminars and consulting projects. Let me take a stab at simplifying the concept.

HOW TO GET TO CALIFORNIA

If I asked you to tell me the best way to travel from Atlanta to Los Angeles, what would you say? When I ask that question in our seminars, most people say by plane. When they respond so quickly, they are making assumptions about the trip. They are assuming that there is sufficient money available to buy a plane ticket, that time is of the essence, and that air travel is generally preferred. (That says a lot about our culture.) The real answer is, "It depends."

Suppose I add something to the question and ask you to tell me the best way to go if you have only $100. What would you say? Now the range of options may be limited to hitchhiking and stowing away. Suppose I add that money is no object and that you have to be there within 12 hours. What would you say? Now the only option is to go by plane, and since money is no object, why not charter a jet? Suppose I say you have to be there in 12 hours

and spend the lowest amount of money possible. What would you say? Now the range is even narrower and probably entails getting the cheapest possible coach plane ticket. In that example, "12 hours" is a constraint and "the lowest amount of money possible" is the objective function. In optimization terms it would look like this:

- Objective function = minimize total money spent
- Constraint(s) = arrive within 12 hours

Without an objective function *and* constraint(s), any answer is right and any answer is wrong. Since most business, supply chain, and inventory decisions are not framed with optimization, how are business, supply chain, or inventory decisions made? Unfortunately, it often comes down to who can write the most caustic e-mail, who has the boss's ear, who has the most political clout, and the like.

INVENTORY OBJECTIVE FUNCTIONS

An optimization statement has two components: an objective function and constraints. When it is isolated to inventory, the optimization becomes a matter of finding the inventory level that yields the best possible financial performance for the business and supply chain, subject to fill rate, response time, shipping frequency, and storage capacity constraints.

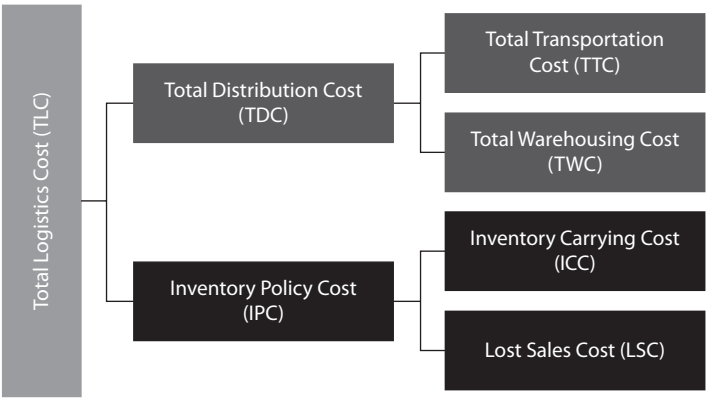
The RightStock model uses a menu of objective functions for inventory decision optimization. They are all related to financial performance and include the impact of inventory and fill rate on revenue, expense, and capital. (This is a major departure from most supply chain philosophies, tools, and metrics, which typically focus solely on the impact of decisions on expenses or operational performance.) RightStock objective functions include maximizing return on invested capital, maximizing Inventory Value Added™ (IVA), minimizing Inventory Policy Cost™ (IPC), and maximizing gross margin return on inventory (GMROI). There will be a much more comprehensive explanation of these objective functions in Chapter 2, Section 2.6.

INVENTORY CONSTRAINTS

If all we had was an objective function, logistics optimization would be easy. Admittedly facetious but regrettably common, here is a story line that is played out in many companies. Let's consider each of the total logistics cost components (Figure 1.3) independently. The first is transportation. There are fuel costs, regulatory hassles, poorly performing carriers—the list goes on. Transportation has become so expensive and complex that we may just decide to stop trying. The second component is warehousing. All the JIT, lean, and Six Sigma books suggest that warehousing is non-value-added and just plain bad for business. Let's close the warehouses. The third component is inventory carrying. Even though inventory is still an asset in accounting, we all know it's a liability (borderline illegal in some companies) and politically incorrect in the current JIT, lean, Six Sigma environment. We need to stop carrying inventory. Since there is no inventory, there will be no customers, and so lost sales cost is eliminated. These factors all work together to completely eliminate total logistics cost and the inventory that goes with it. We win, right? Wrong!

In addition to common sense, what should prohibit an organization from going down that road to ruin? A customer service policy (CSP).

Figure 1.3 Total Logistics Cost Elements for Optimization



A RightChain customer service policy is segmented by channel, ABC customer class within a channel, commodity, and SKU class within a commodity (Figure 1.4). The customer service policy establishes targets that must be met for fill rate, response time, delivery frequency, delivery quality, packaging, and any other stipulated dimension of customer service. Those requirements serve as constraints in supply chain logistics optimization. An example supply chain logistics optimization statement from a recent service parts client follows.

Objective Function

- Minimize total logistics cost

Constraints

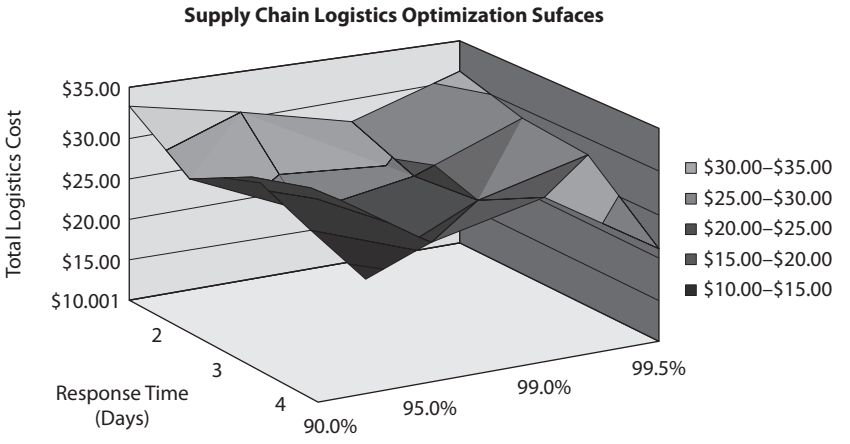
1. Fill rate ≥ 97%
2. Response time ≤ 48 hours
3. Delivery frequency = three times per week
4. Shipping accuracy ≥ 99.7%

Figure 1.5 is an illustration of an optimization. Note that the customer service policy yielding the lowest total logistics cost is a response time of three days and a fill rate of 99%. (That is not always the case; it just happened to be for one particular SKU for this particular client.) The tricky part is that as fill rate increases, inventory carrying cost, warehousing costs, and potentially transportation costs increase while lost sales costs decrease. Those dynamics and interdependencies are shown on one axis. As response time decreases, transportation costs, warehousing costs, and potentially inventory carrying costs increase (depending on whether the response time requirement is met through more expensive transportation or more warehousing close to the customer), but lost sales cost decreases. Those dynamics and interdependencies are shown on the other axis.

Figure 1.4 Multichannel Customer Service Policy

RightServe™ Customer Service Optimization System™			**Shipment Preparation Time**	**Delivery Frequency**	**Order Cutoff Time**	**Fill Rate**
Channel	**Customer Class**	**SKU Class**	*Internal Prep Time*	*Time Between Deliveries*	*Latest Time for Order Placement*	*Inventory Availability and Allocation Rules*
Channel I	A	A	Same Day Pickup-9:00 AM	Twice Daily	10:00 PM	99.5% - Allocation
		B	Next Day - 12:00 PM	Daily	9:00 PM	98% - Allocation
		C	72 Hours	Weekly	8:00 PM	96% - Allocation
	B	A	Next Day - 12:00 PM	Daily	9:00 PM	99% - Right of Refusal
		B	Two-Day - 12:00 PM	Weekly	7:00 PM	94% - Right of Refusal
		C	Leadtime by SKU	Monthly	5:00 PM	91% - Right of Refusal
	C	A	Two-Day 12:00 PM	Weekly	5:00 PM	Delayed Acknowledgment
		B	72 Hours	Monthly	3:00 PM	Delayed Acknowledgment
		C	One Week	Monthly	3:00 PM	Delayed Acknowledgment
Channel II	A	A	Next Day - 12:00 PM	Daily	7:00 PM	97.5% - Allocation
		B	Next Day - 12:00 PM	Daily	7:00 PM	93% - Allocation
		C	Two-Day - 12:00 PM	Weekly	6:00 PM	84% - Allocation
	B	A	72 Hours	Weekly	5:00 PM	94% - Right of Refusal
		B	72 Hours	Monthly	6:00 PM	89% - Right of Refusal
		C	One Week	Monthly	7:00 PM	77% - Right of Refusal
	C	A	One Week	Monthly	4:00 PM	Delayed Acknowledgment
		B	Leadtime by SKU	Monthly	5:00 PM	Delayed Acknowledgment
		C	Leadtime by SKU	Monthly	6:00 PM	Delayed Acknowledgment

Figure 1.5 Supply Chain Logistics Optimization Surfaces



A strictly inventory optimization statement would include one or more of the following objective functions and one or more of the following constraints (each will be explained in much more detail as we proceed through the book):

Inventory Objective Function Candidates

- Maximize gross margin return on inventory
- Maximize Inventory Value Added
- Minimize Inventory Policy Cost

Inventory Optimization Constraints

- Fill rate $\geq$ target
- Response time $\leq$ target
- Shipping frequency $\geq$ target
- Inventory $\leq$ storage capacity

Determining and implementing the inventory level that satisfies the required constraints and yields the best financial performance is inventory optimization.

1.4 TO(O) LEAN OR NOT TO(O) LEAN?

In the late 1980s I had the unique privilege of leading a major study for the U.S. government comparing U.S. and Japanese logistics systems. During the study I interviewed business and supply chain executives in many large Japanese organizations. Not surprisingly, one of them was Toyota. I spent significant time with the developers of the Toyota Production System and their professor. One of the stories they shared explains more about the Toyota Production System than all the books I have ever read on the topic.

The Toyoda (the company name was created from the family name) family started as rice farmers. They became wealthy when they invented mechanical harvesting equipment for that crop. At some point they decided that if they could make rice harvesting equipment, they could also make cars. The production concepts did not translate very well, and the automaking venture almost bankrupted the family. The head of the family decided to hire a new engineer from outside the family and gave him one year to develop a new way to make cars. To make a long story short, that young man came up with a way to profitably make cars in an island nation (self-contained) with few natural resources (no waste), limited habitable land (no space), and locustlike industrial congestion (perfectly orderly). The Toyota Production System was born out of those unique geographic, business, and cultural conditions.

Those are not the same conditions that exist in the United States, Western Europe, Eastern Europe, China, Mexico, Brazil, and many other places. (The head of the supply chain for one of the major automotive companies operating in those other countries shared with me that they call lean "anorexia.") There are many beneficial ideas and concepts in the Toyota Production System and its paradigm children, but they are not all applicable and are not all best practices. They were for Toyota but are not for everyone. That's why we coined the phrase "Don't philosophize, optimize."

1.5 THE INVENTORY JOURNEY

Inventory Strategy is a journey through increasingly advanced inventory strategies and increasing levels of inventory management maturity. The book employs a comprehensive mix of case studies, analytics, and illustrations to confront prevailing inventory paradigms, reestablish the fundamentals of inventory, and optimize inventory levels across financial, service, and operational perspectives. The book and its underlying RightStock model present a proven, fact-based, balanced, and logical means of determining the proper role and level of inventory in supply chain strategy.

Chapter 2 is devoted to inventory fundamentals: Inventory 101 if you will. I am often aghast at the misunderstanding and misapplication of inventory fundamentals. I included those fundamentals to establish a foundation for understanding more advanced inventory interdependencies within a supply chain, within the company, and with other companies. Inventory fundamentals covers (1) inventory integrity, (2) inventory philosophies, (3) inventory types, (4) out of stock conditions, (5) planning parameters, (6) financial terms, (7) demand terms, (8) decision variables, and (9) inventory interdependencies.

Chapter 3 teaches our RightStock methodology for optimizing inventory levels: Inventory 201. The model moves progressively through the seven steps of optimizing (1) SKU portfolios, (2) forecast accuracy, (3) lead times, (4) lot sizes, (5) deployment, (6) visibility, and (7) inventory carrying rates.

Chapter 4 presents the role of inventory in supply chain strategy: Inventory 301. We begin by developing a full definition of supply chain logistics; then teach the role of inventory in customer service, supply, transportation, and warehousing; and end by illustrating the role inventory should play in fully integrated supply chain strategies.

A Glossary of key terms and formulas is provided at the end of the book.