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Evolution of the POM Discipline

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PART I

The Remarkable History of POM
1 EVOLUTION OF THE POM DISCIPLINE

Martin K. Starr, Sushil K. Gupta, and Christopher Tang

1 Introduction to Evolving POM

Note that, for the purposes of this chapter and for the Companion as well, we have chosen to use the acronym POM to stand for Production and Operations Management, Operations Management, and Production Management, therefore embodying all possible usages in a single acronym.

Even as we start this chapter, we know that our interest in this chapter's mission is based upon using history to project the future. There are many advocates who say that only by knowing where you have been can you prognosticate where you are heading in the future. By describing POM's evolution, and recognizing the real drivers of the field, we may be able to prophesize the future. At the very least, we can discuss what POM is capable of becoming. Additionally, there is another major point that is concerned with how POM can fail and what POM should avoid.

This POM Companion only begins to map the surface of the evolving POM discipline. There are so many aspects to the field that even those of us who have been steeped in its development are somewhat dazzled by the variety. Each facet has its own group with intense advocacy and remarkable depth of investigation. This is true because POM represents a blending of Science and Art. There is the Science of technology and the Art of management. Taken together, and rendered properly, successful leadership arises.

We capitalize the first letters of Science and Art (S&A) because we are dealing with many applications of the generic structure of both S&A in the same way that Chemistry and Physics are both employers of legitimate Science. Similarly, both Painting and Sculpture utilize all of the most fundamental principles of Art. POM, as with architecture, uses both Science and Art to predict what will work and to forewarn what will not.

Looking back is instructive for other reasons as well. We can observe that the field of POM has gone through many changes that can be called evolutionary or revolutionary—depending upon the scholars’ time frame. In this chapter, we choose several ways of viewing developments over the recent past. Our attention will be focused on the recent past because that will constitute the most relevant history for explaining foundations upon which the future of this field is likely to be constructed.
One approach identifies three milestone events (Sections 3, 4, and 5). A second approach examines the four industrial revolution eras (called IR 1.0, IR 2.0, IR 3.0, and IR 4.0) as found in Sections 6.1, 6.2, 6.3, and 6.4. These are two different ways of slicing the apple. Each provides insights and perspectives that are useful as frameworks for understanding why POM cuts across so many areas of application that are seemingly unrelated to each other except in the context of the rich fabric of a great society. We have to conclude that certain elements are common to all of these areas of application. Additionally, it will be very evident why, at first, POM was centered on manufacturing but then its applicability spread to services and many unconventional applications. At first, these milestones read as if they only apply to manufacturing, but that is misleading. As technology expands, so does vision. That is why we also use “industrial revolution eras” in this first chapter. The era perspective shows how services evolve to envelop and utilize the best of manufacturing processes and procedures.

Some of the elements of commonality are their dependency on competent process design to provide product supply that is scalable to the level of demand. Quite clearly, “products” in this context refer to both goods and services. Also evident is the commonality of the perception of product quality by the consumers of these goods and services. This measure of quality includes both speed of delivery and important product attributes. Although cost is seldom included as a quality attribute, it is a critical decision factor for most consumers. POM is involved in all three of these critical dimensions of process to product/service output performance. Each chapter in this POM Companion shows that the same commonalities apply to radically different domains of application (e.g., sports, military, healthcare, hospitality, disaster management, and farming in New Zealand).

Before concluding this “Introduction to Evolving POM,” please note our strong preference towards influencing the future rather than trying to forecast what the future will look like. Unambiguously, we chose the strategy of achieving active impact rather than benefiting from passive forecasting. The thirty-seven chapters of this POM Companion should be viewed in this perspective. These chapters are meant to influence future developments rather than attempt to predict what the future will be like. That is why most chapters conclude with a section describing research opportunities for young scholars and why many chapters have a section that provides “implications for practitioners.” Research that is intense and honest is useful on its own, but we also need brilliant insights and astounding breakthroughs that can be expanded upon for the future.

2 The Value of Historical Perspective for POM

The first steps out of the Stone Age came with the metalworking of copper (about 10,000 years ago). This actually precedes any real evidence of humanity’s ability to read and write. Ages were named for the development of skills with materials starting with the Stone Age (9300 to 3300 BCE). Then, came the Bronze Age (3300 to 1300 BCE) followed by the Iron Age (1300 BCE to 700 CE). These numbers are approximate and depend on locations and contexts (e.g., scholars point to Early, Middle, and Late Iron Ages). All of this is definitely pre–POM and yet serves as a vital precursor to what POM may become in the Information Age (1950 CE and on).

We have no intention of describing (in any detail) production and operations developments during the Renaissance period of 1300 to 1600 CE. This rebirth of art and intellect began in Italy and spread across Europe, ending around 1600 CE with the major Reformation of church and state. However, centuries before 1300 CE, there was production of food and shelters, clothing, and other necessities such as shoes, water jugs, and kilns for cooking. Production of tools of war including ships, chariots, and means of hurling projectiles antedates Alexander the Great (356 BCE to 323 BCE).
As we move through eons of time, the year 1500 CE stands out as an important POM threshold because it signals the beginning of the artisan craft guilds. Often there was one guild for each trade (e.g., bakers, brewers, carpenters, cobblers, and stonemasons). Guilds imposed rationality and consistency on each trade’s production. Most Guilds inspected product for violations of quality subject to standards set by the members, e.g., in parts of Europe the blending of gruit for beer was a closely held secret of the Gruit Guilds, which were responsible for high-quality beer. (Gruit—also from the Dutch word gruyt—a herb mixture used for bittering beer before the extensive use of hops.) The beer game aside, one can say that 1500 CE marks the first coherent efforts to organize a great variety of production systems in terms of supply and demand, cost and price, quality and quantity. It is interesting how often the motivations were beer and military factors.

3 First POM Milestone—The Division of Labor

The first major POM milestone occurred when the 18th century was about 75% completed. This milestone came in the form of a book that promoted the benefits of employing the division of labor in a factory setting. Written by Adam Smith, the book was entitled *An Inquiry into the Nature and Causes of the Wealth of Nations*. This two-volume treatise (published in the same year as the American Declaration of Independence) was followed by three new editions amended by Smith and a fourth edition in 1904—all of which had the same title (Smith 1776).

These texts examined the economics of national wealth, recognizing that the “specialization of jobs” in factories provided substantial commercial benefits. The “division of labor” is another way of describing this early effort to design for manufacturing (DFM) in terms of “the division of labor.” DFM is related to process design that promotes job improvement by means of repetition of limited, circumscribed activities by individuals. Another major point that Adam Smith made was the way in which supply and demand achieve a state of equilibrium (he called it the invisible hand). In fact, it was the way in which the supply chain operated that caught Smith’s attention. The name “supply chain” was unknown at that time, but the invisible hand referred to market forces as controlled by managers. Smith’s *Wealth of Nations* put forward concepts that led to profound changes in the nature of production systems. It also foretold that remarkable societal cataclysmic changes were beginning to occur.

So often, this important book is mentioned without dissemination of its contents. To better understand why this publication was a landmark event and turning point, we believe that it helps to glimpse a part of its table of contents (as shown below). Here are a few of the chapter and section titles (we employ the British spelling for “labour” because that is the way it is written):


Book I: “Of the Causes of Improvement”

  Section I.1: “Of the Division of Labour”
  Section I.2: “Of the Principle which gives Occasion to the Division of Labour”
  Section I.3: “That the Division of Labour is Limited by the Extent of the Market”

Book II: “Of the Nature, Accumulation, and Employment of Stock”

Book III: “Of the different Progress of Opulence in different Nations”

  Section III.3: “Of the Rise and Progress of Cities and Towns. . . .”

Book IV: “Of Systems of Political Economy”

Book V: “Of the Revenue of the Sovereign or Commonwealth”

Section V.2: “Of the Sources of the General or Public Revenue of the Society”

This book was widely read. The thesis enabled risk-takers to assess the value of shifting their investments from the old style of doing business to a newer one that built factories (especially for the textile industry). It is a fair guess that Smith’s work accelerated the rate with which a variety of POM-enabling events (e.g., inventions for textile mills) followed.

Methods for employing this “division of labor” have had major impacts on productivity enhancement, and they are often part of successful POM implementations at the present time. One of the first examples of how effective specialization can be was the way factory operations were designed at the Highland Park Ford plant in 1913. Henry Ford was a master at successfully implementing the “division of labor” concept on Ford’s moving assembly (production) line.

This production system reduced the chassis assembly time from 12.5 hours to 1.5 hours with great cost reduction. This enabled Henry Ford to pay workers $5 per day, twice what they were originally being paid. At that pay scale, workers on the assembly line could buy a Model T with about four months of pay, and many of them became owners. Ford was applauded for enabling his workers to become customers.

3.1 The Holistic Production System of Volvo
(Opposite to Division of Labor)

The holistic production system of the Volvo Uddevalla plant in Sweden (which opened in 1985) provided a counter example of job specialization. The very opposite of division of labor was used. Employees were part of an assembly team that was grouped around a single fixed position for auto assembly. Every employee was trained to do all of the jobs required to assemble a Volvo. The production method was called “naturally grouped assembly work.” Employees moved around the car in well thought-out sequences to accomplish assembly. Unlike Ford assembly, the car chassis never moved.

What happened to this seven-year experiment is partially summarized in a report whose title is somewhat confusing, “The Uddevalla Plant: Why Did It Succeed with a Holistic Approach and why Did It Come to an End?” (Nilsson 2007). The report states that both the traditional (Ford-type) and the holistic approach were seen by management as having equivalent efficiencies and that the costs at Uddevalla were seen as higher. The report also states that this conclusion was not true, implying that costs were lower and efficiency was higher at Uddevalla. Quoting from the report, “Unfortunately the Volvo Uddevalla plant in its tragic premature closure will not be able to demonstrate the success of the model.” This provocative conclusion seems to offer ample reason for future research on the validity of the division of labor thesis.

3.2 Division of Labor Applied to Services

It should be noted that “division of labor” has had an important influence on service systems as well as manufacturing. A few helpful examples come readily to mind. The use of specialists in the healthcare systems are the norm and not the exception. So many different skills are required in a hospital that it is even more diverse than a business school faculty. The pastry chef in a gourmet restaurant is not expected to cook the soup or serve fine wines. Call center designs are predicated
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on the advantages of separating requests and directing them to specialists in each type of query. Often, a robot sorter is used to direct calls to the right specialist.

There are ample opportunities to conduct important research on how best to use the division of labor to improve productivity in the service sector. General practitioners in the medical field are the generalists who can see the big picture. Specialists may understand particular parts of the body or mind, but the generalist’s point of view is essential for proper diagnostics. This perspective is entirely applicable to managers of organizations who require input from staff specialists in order to reach decisions that reflect systems factors.

We would be remiss not to note that service robots have assumed an important role in many industries, reflecting years of development. Joe Engelberger—the so-called father of robotics—wanted to develop robots that could work in hazardous environments that were harmful to humans. He was chairman of the board and champion of robots at Transitions Research Corporation (TRC), which brought out Unimate, the first industrial robot in the U.S. in the 1950s. TRC specialized in service robots including HelpMate (a service bot that did the work of hospital orderlies).

Automated voice response systems have a commanding presence in taking reservations for airlines, restaurants, etc. Not only do they schedule appointments, but they also determine the best connective path for incoming calls. With the further development of artificial intelligence (AI), we can expect to obtain great diagnostics from computerized medical-assist programs. IBM’s supercomputer Watson may be close to a tipping point in finding cures for diseases that have ravaged both developed and underdeveloped economies. To conclude, it would appear that the application of the best “division of labor” in service organizations is a fertile area for scholarly research.

4 Second POM Milestone—Interchangeable Parts (IP) and the Science of Tolerance Ranges

Ford’s assembly line could not have functioned if car doors had to be customized in order to fit each unique chassis. For the Ford system to work, all parts had to be interchangeable. Every door (e.g., the front seat driver’s door), as it comes from the metal stamping machines, must fit the appropriate chassis door opening of the matching car model. Color is a different issue than tolerances. Color matching requires scheduling the same color door and chassis to meet at the right point in time and place on the production assembly line.

The concept of “interchangeable parts” assumes that components can be selected at random (from a batch of similar parts) and that they will fit together without requiring any make-fit work. It is important to note that make-fit procedures were the norm long before and even long after cotton gin inventor Eli Whitney (1765–1825) conceived of interchangeable musket parts. It was the only way that he could fulfill a 1798 Congressional contract to build 10,000 muskets for the U.S. Army by a given date.

Selective assembly is an alternative mode of assembly where pairs of parts having the best fit are selected. This option would override random selection when very tight tolerance matching is essential. For a deeper discussion and appropriate references, the Wikipedia article on “Interchangeable Parts” is a rather helpful starting point. Additionally, consider researching the article for “Honoré Blanc,” another pioneer for interchangeable parts who, as the French counterpart of Eli Whitney, made a big impression on then American Ambassador to France, Thomas Jefferson.

Whitney developed specifications that would permit 10,000 of each part (e.g., triggers, stocks, barrels, etc.) to be substitutable for one another. One trigger was like another trigger, and that not only reduced the cost of assembling the muskets but allowed for rapid assembly. The idea of interchangeability was being developed in France and Sweden and quite possibly other places in
Europe as well. Wherever it was tried, it resulted in far better fabrication and assembly, which led to its adoption in factories after 1800. For this reason, at least in some circles, Whitney was known as a pioneer in the development of the American manufacturing system.

We are not born with the innate knowledge of how to design appropriate tolerance ranges so that part A fits “perfectly” into part B. For example, keys must fit the slot in the cylinder of locks just as doors must fit into doorframes. Logical use of fitting tools such as files would enable a worker to approximate what is required. This is called custom fitting. However, the method of gradually approaching a good fit incrementally is very costly and time consuming. Henry Ford’s assembly line would not have achieved “mass production” of the Model T without the realization of the need for interchangeable parts. An extension of this knowledge has led to the meta-level of understanding that is required to achieve modular production (Starr 2010). Modular products have many varieties by simply interchanging components, e.g., cars with different engines and tires, phones with different memory levels. This is a higher degree of interchangeability than is achieved by standardization described in Section 5.1 below.

Engineers are trained to design tolerance ranges for interchangeability. The concepts that are required must take into account two additional phenomena. First, stamping dies (for example) wear down. This means that the sizes of components change over time (by usage) as they come off the production line. It is likely that the first door coming off the production line fits perfectly within the door frame of the first chassis that is constructed. That is because the tolerances are properly designed. Now, taking mechanical wear into account, the second door that is made is just a bit wider, and the chassis door frame maybe, just a bit narrower. The process of widening and narrowing continues until the door no longer is a perfect fit. Instead, it may wobble or cohere. Engineers know that it is time to replace the old and worn dies with new ones. No one is surprised. Designers, and workers on the assembly line, knew that this would happen. Eventually, stamping dies are always re-tooled or replaced. This production problem is well understood. It is competently addressed in most cases by quality control experts.

Now, let us turn to the second phenomenon, which was not understood until the early 1900s. That is when Milestone 3 was achieved and surpassed by Walter A. Shewhart who, in 1924, wrote a critical memorandum to his boss at Bell Labs (George Edwards) in which he developed the essential principles and fundamental concepts of statistical quality control (SQC).

5 Third POM Milestone—Statistical Quality Control (SQC) and Standardization

In an idealistic world, interchangeable parts would be identical. In a realistic world, that is not possible. This conundrum explains why Milestone 3 was such an elusive and critical next step that had to be traversed before the science of tolerance limits could be properly formulated by a host of statisticians with applied POM leanings and training.

Gratefully, we acknowledge that we do not have to repeat the biographic materials of these scientists because there is excellent coverage of twelve of the most important such individuals in Chapter 7, Section 4, which presents “Key Figures” in Quality Management.

We will, however, name these twelve pioneers who developed the fundamental concepts/methods related to the variability of production output. These are (in the order of their appearance in Chapter 7, Section 4): Frederick W. Taylor, William Sealy Gosset, Ronald Alymer Fisher, Henry Ford, George D. Edwards, Walter A. Shewhart, W. Edwards Deming, Armand V. Feigenbaum, Joseph M. Juran, Kaoru Ishikawa, Taiichi Ohno, and Philip B. Crosby. Each one of these outstanding practitioners and/or academics contributed to the accomplishments that were essential to achieve completion of the third Milestone.
When combined with empirical observations of the real world, probability theory showed that at some reasonable level of product dimension measurement some significant degree of variability would be observed. Shewhart showed how to measure, track, and control variability. Control could only be exercised if one could determine whether observed variability was an inherent part of the systems variability or an external and removable cause of variability.

There could be no correction (reduction of variability) of inherent statistical variability caused by endless numbers of trivial factors that add up to a significant amount of total variation. Gears heat up and expand at different rates. Each part of any machine provides its own unique underlying characteristics. For example, small vibrations from each and every machine element combine to produce a symphony of little causes.

Instead of inherent causes that cannot be eliminated are assignable causes that can be tracked, traced, and removed.

The statistical theory of variability is fundamental to fabrication of parts and components as well as to operations and activities, including time to maintain and repair a system as well as to service customers. For example, accident rates have been studied for stability where stability indicates that all assignable causes of variability have been removed. To illustrate, let's say that workers trip occasionally over a crack in the plant floor. Smoothing it out removes an assignable cause.

The variability of people's skills and behaviors are exemplified by the inability to drive a golf ball in an identical way—with exactly the same results every time you tee off. Workers using machines reflect the same phenomena in which machines, muscles, and vision each contribute some degree of variation. The distribution of total variability along many different dimensions must be understood to control the process and provide a satisfactory product to the customer.

5.1 Standardized Parts and Operations

Without standardization, costs increase and quality decreases substantially. For example, we take for granted the fact that the light bulbs we buy in the hardware store or supermarket fit the lamps in our homes. That is because in the U.S., the E26 is a standard light bulb screw base for a 110-volt outlet. The European variant, rated at 220 volts, is called E27 because it has a 27-mm diameter whereas the U.S. socket has a 26-mm diameter. An E26 bulb can fit into an E27 base, and vice versa. Often times, there are differences between European products based on metric system measures and U.S. products based on the English system of measurement.

There are at least ten different screw bases for light bulbs. That is a lot of choice within a convention, but there are other dimensional designations as well. The most common type of residential light bulb is the “A” shape. An A19 would signify that the width of the bulb at its widest point (in eighths of an inch) is 19 divided by 8, which equals 2.375 inches in diameter. There are different sizes for different uses. For example, the Edison screw fitting is a system of screw mounts developed by Thomas Edison in 1909 under the Mazda trademark. Most have a right-hand, threaded metal base, which is turned clockwise to tighten in the socket. However, the New York City subway lightbulbs are turned counterclockwise to tighten, which keeps them from being stolen for use at home.

Typical incandescent A-type bulbs work with AC or DC. They are very inefficient, converting less than 2% to 3% of the energy they use into visible light; the remainder is converted into heat. Another measure of importance is how many lumens are delivered per watt, which is called luminous efficacy. The expected lifetime of such bulbs is in the thousands of hours and so, where the cost of replacing burnt-out bulbs is large, preference goes to LEDs. In many countries, regulations have been passed to phase out incandescent bulbs in the relatively near future.
We do not intend to present more than this cursory history of the light bulb (which, if properly pursued, is both fascinating and instructive). Dimensions and tolerances for screw bases are standardized in ANSI standard C81.67 and IEC standard 60061–1. Who are ANSI and IEC? ANSI refers to the American National Standards Institute, which is a private non-profit organization that oversees the development of voluntary consensus standards for products, services, processes, systems, and personnel in the U.S. The IEC is a similar organization (International Electrotechnical Commission) which sets international standards especially for electrical, electronics, and related technologies.

To the knowledge of any system of standards, we must now add the requirement that tolerances be understood. A lamp base of 26 mm must have an associated tolerance range for both the base and the socket into which the base screws. We will employ numbers that seem reasonable but are arbitrary (not related to any manufacturer of light bulbs). When tolerance ranges are proposed for a bulb base (such as 26.0 ± 0.1 mm), it connotes that the base diameter could be as narrow as 25.9 mm (26.0 − 0.1 = 25.9) or as wide as 26.1 mm (26.0 + 0.1 = 26.1).

The statistical variability of the system of production (persons and machines) will be expected to fall within that range (say) 99.5% of the time. If the base measures have a normal distribution with a mean of 26.0, it is quite feasible to determine if the given system is capable of achieving these results. It is also evident the socket maker must provide a tolerance range of diameters that will allow all bulbs that conform to be accommodated.

The three milestones have created an environment in which global trade is feasible for makers of bulbs and makers of lamps. The customer is able to buy the commodity of light at a very reasonable price. If all three milestones had not occurred with challenges met successfully, the world would be a much darker place.

We will now try taking a different cut at describing the evolution of the POM discipline. Instead of using critical events, we will describe a sequence of industrial revolution eras. The timeline consists of the four eras in Section 6. The first of these eras begins around 1760, which predates Adam Smith’s publication of *The Wealth of Nations* by sixteen years. It is said that Smith was working on his manuscript for about nine years prior to its publication. Events were moving the Western World toward accelerated industrialization.

6 Four Industrial Revolutions—IR 1.0, IR 2.0, IR 3.0, and IR 4.0

Strictly speaking, industrialization is defined as the process by which a country (or group of nations) is transformed by a variety of forces from an agricultural society to one based on the manufacturing of goods and the production of services. Craftsmen who customize products are replaced by workers on an assembly line. At least, that is what was meant by the term “industrial” as in the First Industrial Revolution (which we will call IR 1.0 for reasons that will be obvious as we proceed).

6.1 The First Industrial Revolution (IR 1.0), 1776 to 1840

The textile industry was revolutionized by water power and steam power in the United Kingdom. Shortly after the American Revolution (1776), the same occurred in the emancipated colony across the Atlantic Ocean. Division of labor played an important part in disrupting the existing systems for producing textile products. Possibly, the most significant impact of this disruption was the increase in personal wealth. The standard of living for the general population started to increase, and it continued to do so beyond the conclusion of IR 1.0, which is generally stated to be 1840. We have spent ample time on the effects of the first industrial revolution.
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Clearly, it created the foundation upon which POM was conceived and developed. The second industrial revolution had an even more profound effect.

6.2 The Second Industrial Revolution (IR 2.0), 1840 to 1914

The second phase is said by historians (who are in charge of such distinctions) to have begun in 1840 and continued until about 1914 which marked the start of World War I. During this period (which is also called the Technological Revolution), steam was adopted as a major power source for manufacturing as well as transportation. Iron making became a major industry as coke was substituted for charcoal. This change in production method created higher-quality iron and steel products, which were made at significantly lower costs. The effects rippled out, impinging on many products as well as on the construction of tall buildings and expansive railroad systems.

This was followed by electrification of factories. Telegraph lines changed the character of global communication. Automobiles were altering transportation. Paper production in conjunction with printing presses allowed for the mass production of newspapers and books. Petroleum became a source of energy that was portable for kerosene lamps and heaters. Mass produced pencils were a social phenomenon. Electric lights and fountain pens epitomized an era of unparalleled invention. IR 2.0 represented an exceptional time that affected large numbers of people.

Division of labor became ubiquitous for fabrication. It continued to characterize services. There was a clear distinction, however. Specialization in manufacturing applied to small subsets and sequences of the total activities required to make and assemble a product. Specialization for services was far more encompassing—as in healthcare and animal husbandry. The specialist was a generalist for a particular application.

Shoes are a good example of the transition that occurred with the advent of IR 2.0. Shoes had been crudely and custom made by shoemakers for ages. The right and left shoe were identical until about 1820. In 1812, Marc Brunel developed machinery for the mass production of boots for soldiers of the British Army. By 1815, manual labor was cheaper, and Brunel’s system ceased to be used. However, Lyman Blake invented a shoe-stitching machine in 1856, and by 1864, it was known as the McKay stitching machine. By 1864, factories all over New England in the U.S. began to make shoes.

Iron made by rolling mills and hot blast furnaces (around 1830) was slow and costly. This was disrupted by the first inexpensive industrial process for the mass production of steel (Bessemer’s process was patented in 1856). New capabilities of steel were explored allowing bridges to be built across greater spans than ever before. The Brooklyn Bridge was the world’s longest suspension bridge at the time. It was completed in 1883 (McCullough 2012).

POM project management students are likely to profit by reading David McCullough’s book referenced above as well as his book about the Panama Canal (McCullough 2001), which epitomized IR 2.0. This very difficult project was carried out in two stages. The French began in 1881, having completed the sea-level Suez Canal ten years earlier. Troubles abounded, and work was abandoned in 1888. A project group led by American engineers restarted the project in 1904. Locks were added because the tidal range at the Pacific was 20 feet, whereas it was only 1 foot on the Atlantic side. Completion occurred in 1914 after much loss of life due to yellow fever and malaria. The Panama Canal expansion project is near completion now and will lead to bigger ships requiring deeper harbors and greater container capabilities.

Although POM still did not exist as IR 2.0 ended, its most important precursor, industrial engineering, was being born in the early years of the 20th Century. In fact, industrial engineering became a major option at every engineering school in the U.S. after World War II.
Inventions during IR 2.0 came so regularly that it should have been named “the age of invention.” In contrast, these days, 63% of all shoes are made in the People’s Republic of China. We will get to such shifts in production locations, which are directly related to outsourcing labor-intensive work because of lower labor costs. “Outsourcing,” which spans IR 3.0 and IR 4.0, has taken on serious pejorative connotations. There is little doubt that the emergence of powerful and inexpensive robotics during IR 4.0 will change this discourse.

6.3 The Third Industrial Revolution (IR 3.0), 1914 to 1999

The starting and ending dates for the Third Industrial Revolution are not agreed upon. The author, Jeremy Rifkin wrote a book called *The Third Industrial Revolution* (Rifkin 2011). In it, he contends that the Internet and renewable energy should be labeled as the third industrial revolution. It is our contention that the era between WWI and the end of the 20th Century deserves that label. The third Milestone was not fully developed until well after 1914. Instead, we have identified a new POM inspired (intellectual) movement, which is known as Industry 4.0 (as equivalent to IR 4.0).

The shift between IR 2.0 and IR 3.0 was an acceleration of existing trends plus a lot of new very disruptive technology. Using textiles as an example of acceleration of existing trends, the cottage industry’s “putting-out system” was totally disrupted and obliterated. The main power source for everything that moved was steam made by burning coal. This was gradually, and then almost entirely, disrupted by electrification with many motors and engines being energized by petroleum products. Realization of economies of scale led to high-volume production systems sustained by increased capabilities of marketing to generate sufficient demand to support mass production.

During this era, industrial engineering (IE) was born. In the U.S., the first department of industrial and manufacturing engineering was established at Pennsylvania State University in 1909. In these early years of the 1900s, process analysis was being rationalized and legitimized by IE practitioners (who had never heard of POM). Great industrial engineers such as Frank Bunker Gilbreth Jr. and Lillian Moller Gilbreth were talking about process improvement both in the home and in the factory. Lillian gave lectures at MIT about efficiency in the kitchen. Time and motion studies were the method of studying process activities and the term efficiency expert had a glamorous ring to it. It sustained its vigor and importance for practitioners and academics alike into the third IR 3.0.

From 1914 to 1990, the computer evolved from a huge amalgam of vacuum tubes, patch cables, and switches to lightweight laptops with solid-state disks (SSDs) that were also called flash memory. Eventually, these advancements would lead to even smaller and lighter smart phones that had more power than the famous ENIAC at the University of Pennsylvania (1943–1945). The Advanced Research Projects Agency Network (ARPANET) is an important IR 3.0 step along the way. ARPA, the agency, was part of the United States Department of Defense, and it installed and maintained the network connecting many universities and defense establishments in the 1960s. This early packet switching network became the technical foundation of the Internet, something that we think of as a driving force for global communication and information searches. It may seem hard to believe that many opponents existed to this network, but this is due to how the Vietnam years had created plentiful public opposition to anything that involved the U.S. Department of Defense.

Let us continue our brief discussion of IR 3.0 with respect to energy. Petroleum became a major source of energy throughout this period, which made the Middle East into a power broker due to great reserves of traditional oil in the ground. New materials with petroleum bases were developed by chemists. Plastics emerged as a major new material for fabrication with thousands
of new uses (including car doors and bumpers). Coincidentally, this was the era when jet planes cut travel time, therefore enabling international contacts. Huge container ships permitted giant amounts of cargo to be moved economically on a global scale.

With such a background, it makes sense that Japan, while striving to recover from WWII, launched (with the help of W. Edwards Deming and others—see Chapter 7, Section 4.1) an export drive that utilized the automobile industry to become a means for Japan to open very valuable markets in the U.S. Japanese production methods reduce costs and substantially increase the reliability of automobiles. Both of these factors were significant, but the increased reliability of automobiles was a major quality factor for the success of Japanese products.

The Japanese effect on world production methods had a major impact on the POM field, which was beginning to emerge as separate and distinct from industrial engineering (IE). We will consider this major influence by Japan on the POM field in Section 7 of this chapter.

The Operational Research Society was founded in the UK in 1948. The Operations Research Society of America (ORSA) was founded in 1952. The Institute of Management Sciences (TIMS) was founded in 1953. Mel Salveson wrote, "Prior to the formation of the Institute of Management Sciences, TIMS, the prevailing term that came closest to describing its evolving discipline and field of inquiry was scientific management" (Salveson 1997). This chapter in conjunction with Chapter 7, Section 4.1, identified Frederick W. Taylor as the so-called father of scientific management. Salveson continued to write, "However, scientific management was more a collection of admonitions as to what one ought to do to manage effectively. It was not a rigorous discipline nor an evolving body of knowledge based upon traditional scientific methods of research, inquiry, and experimentation." The challenge that Salveson (who was a founder of TIMS) described was a tipping point. TIMS was the beginning of the outright foundation for the Production and Operations Management Society (POMS). All of these societies were precursors to the POM field, but TIMS was directly involved in quantitative modeling and experimentation providing empirical results. There were still many more steps to take along the way.

APICS (originally, the American Production and Inventory Control Society) was founded in 1957. Churchman, Ackoff, and Arnoff published their Introduction to Operations Research in 1957 (Churchman et al. 1957). The military work of Blackett’s Circus (Budiansky 2013) had crossed the paths of military needs for inventory and logistics with that of operations managers and project planners. The models created and reported in the prior references in this paragraph led directly to further developments some of which were reported by Elwood Buffa in his text entitled Modern Production Management (Buffa 1961). Inventory models and queuing systems had meaning for military minds as well as managers responsible for production.

Finally, it all came together when Kalyan Singhal established the Production and Operations Management Society (POMS) in June 1989. Christer Karlsson and Chris Voss were co-founders of the European Operations Management Association (EurOMA) in 1993.

6.4 Industry 4.0: The Fourth Industrial Revolution (IR 4.0), 1999 and beyond

As was true of IR 3.0, this designation of IR 4.0 is also disputed territory. It is our choice to date this future range of new disruptive technologies that are impacting the POM field over an unknown period of time. We believe it is reasonable to proclaim a fourth phase of the industrial revolution (IR 4.0). Each of the prior eras had characteristics that distinguish it from the prior periods.

This era promises new energy sources that may lead to inexpensive power. Rifkin describes people sharing (lateral) power with each other as in an “energy internet” (Rifkin 2011). Such
transactions have the potential to revolutionize the POM domain in many ways. Inexpensive energy costs provide a new income source. They would be derived from alternative sources (not coal and petroleum) such as fusion, solar, wind, and tidal forces. We know that Tesla (led by Elon Musk) has built a huge new plant in Nevada to manufacture lithium batteries for cars and homes. Any means of storing energy more efficiently (with advanced battery designs) is game changing because such power can be used when the sun isn’t shining and the wind isn’t blowing. Such changes would revolutionize the cost structure of fabrication, transportation, home heating, and air conditioning as well as agriculture.

Day-to-day life may include driverless cars and deliveries by drones (see Kiva discussion below). The capability to make spare parts as needed using 3D additive printing is another game changer. It will alter a great variety of systems procedures that require stocking spare parts (e.g., airlines with a globally dispersed network). Military organizations like the U.S. Navy have enormous spare parts inventories.

In 2012, Amazon bought Kiva Systems for $775 million. Kiva makes robots that automate the entire picking and packing process at large warehouses. By the end of Q3 2015, Amazon had 30,000 bots working across 13 of its fulfillment center warehouses. The Kiva robots have significantly improved Amazon’s packing and shipping efficiency and productivity. The Kiva robots are square-shaped, yellow machines that run on wheels. They’re about 16 inches tall and weigh almost 320 pounds. They can run at a steady 5 mph and haul packages weighing up to 700 pounds. Here is a link that shows Kiva bots working together with people at an Amazon warehouse fulfillment center: www.youtube.com/watch?v=quWFjS3Ci7A.

In the bigger picture, robotics will likely be the main change agent during the Industry 4.0 era. Robots change the cost structure that has driven division of labor concepts and produced intense levels of outsourcing. With economies of scale, the lowering costs of robots will favor their use in place of outsourcing to locations where labor-intensive jobs can be done by so-called cheap labor. The paradox of low wages is that as soon as jobs move to low wage regions, the move itself starts a process of wage increases. Quality control gains the advantage of robot’s extremely low inherent variability. The net effect will be for the manufacturing plant to move close to the market where the product is sold. The energy required to make and use robots will continuously decrease, which will be another factor promoting closeness to the market. Robots are designed to do labor-intensive jobs as they can work without stopping for anything except for maintenance. They do not need minimum wages and healthcare benefits. Further, the design of robotic systems will employ an increasing number of very bright and well-trained individuals. Many of them will be able to educate themselves inexpensively using online materials that will become the inventions of Industry 4.0.

For their September 19, 1994, issue, Fortune magazine ran a cover that proclaimed, “The End of the Job.” In retrospect, it was a bit premature, but at least it eventually seemed to be coming true. Another magazine cover that might have been correct would be “The End of the Traditional College Education.” POM currently faces many disruptions across a broad spectrum of its comfort zone. Adaptation in terms of what is taught and how it is taught seems to be called into play. The same holds for research. What is the research agenda (topics, methods, and timing)?

The Business 4.0 era might involve POM in space manufacturing. There are signs of a growing interest in a variety of space initiatives in that direction. Space colonization sounds like content coming straight from science fiction and a return to the throwback days of empires and kingdoms. Astronauts living in space for long periods of time sounded just as far out, and yet we take the people living on the International Space Station as a fact of life. In the same sense, new forms of transport are on the horizon. The rapid transit hyperloop is under serious development. POM faces many challenges that cannot, at this moment, be visualized. A flexible POM is required.
Evolution of the POM Discipline

7 Global Forces Acting on POM

We have shown how a sequence of “industrial revolutions” has impacted POM practice and research. Now, we want to examine some of the particulars in greater detail. For example, during IR 3.0, the Toyota Production System (well known as TPS) played an important role in the development and refinement of many major ideas ranging from lean assembly production systems to company-wide quality control systems.

Since 1980, we have witnessed many manufacturing firms change from “vertically integrated” to “globally decentralized.” During the end of IR 3.0, many developed countries shifted from “manufacturing-based economies” to “service-based economies.” They shifted further to a “knowledge and information-based economy” with the advent of IR 4.0.

POM researchers have gone beyond traditional POM subject areas (scheduling, production planning, inventory control, quality control, etc. (Buffa 1961)). Specifically, POM researchers have ventured into “issue-oriented” topics: supply chains, healthcare, disaster management and humanitarian logistics, service management, and environmental sustainability as well as interfaces with marketing and finance among other areas. The expansion of POM research has led to the use of different research methods including economic analysis, empirical methods, behavioral experiments, and case studies.

Chapter 1 has described impacts on POM practice and research during four different industry revolutions, over some 240 years starting with 1776. With this background of three major milestones and four eras, we can now use Section 8 to discuss how global competition and Japanese production methods led to POM transformations.

8 Global Competition: The Japanese Effect

In the early 1980s, the United States was facing an economic crisis: the prime rate was over 20%, the unemployment rate was over 10%, and the 30-year mortgage rate exceeded 18% (instead of 3.88% as in 2015). The American car industry was losing market share to Japanese car companies. These challenges created strong motivation for POM action.

To improve the competitiveness of the U.S. manufacturing sector, many companies conducted company visits to Japan, did benchmark studies, used reverse engineering, etc. At the same time, there was widespread interest in Deming’s 14 points (Deming 1986) and Crosby’s “Quality is Free” (Crosby 1979). Additionally, practitioners and researchers identified several Japanese manufacturing strategies, e.g., TPS (Toyota’s Production System) (Ohno 1988), SMED (Single-minute Exchange of Die) (Shingo 1985). Besides efficient production systems, there was a push for flexible manufacturing systems (FMS) (Draper 1984) and alternative product development methods so that firms could design and produce new products faster, cheaper, and better (Clark and Wheelwright 1993).

To learn how to implement the Toyota production system, General Motors (GM) formed a joint venture with Toyota (New United Motor Manufacturing, Inc. (NUMMI)). They agreed to produce GM’s Nova and Toyota’s Corolla in the idle Fremont, California, plant of GM. It turned out that Toyota ran the plant and GM was not given access to NUMMI planning methods. Because of the economic downturn in 2008 and a host of management issues, GM discontinued this joint venture in 2010. Within the year, the Tesla Factory moved into the same Fremont, California, plant to produce its Model S all-electric car.

To examine and evaluate lessons learned from Japanese production systems, FMS, and integrated product developments, various POM researchers embarked on groundbreaking research. One key article (Taguchi 1986) developed new statistical methods to improve manufacturing
quality. Another article (Fine 1988) developed quality control models with learning, and incorporates the costs of quality (conformance and appraisal). Porteus (1985) and Spence and Porteus (1987) examined the implications of setup time reduction (e.g., SMED) on inventory planning and capacity planning, respectively. Deleersnyder et al. (1989) wrote one of the first papers to develop an analytical model for designing and managing a kanban controlled production system. Spearman et al. (1990) presented an alternative to a kanban system called CONWIP (constant work-in-process) that has certain practical advantages over push-and-pull systems.

The notion of flexibility in manufacturing received attention after showing how Seiko’s flexible production system enabled the company to produce multiple types of watches on the same production line with minimum changeover time (or cost). Because the term “flexibility” was not well defined, Browne et al. (1984) provided a classification of flexible manufacturing systems. The reader is referred to Sethi and Sethi (1990) for a comprehensive review of the vast literature on flexibility including different types of flexibility and the interrelationships among them as well as various analytical models dealing with these flexibilities. Stecke (1983) was the first to define, formulate, and solve a set of five production planning problems arising from an FMS.

In the context of rapid new product development, Clark and Fujimoto (1989) studied product development projects in the automotive industry and found that, by using overlapping problem solving, Japanese automotive companies were able to shorten their product development cycle time and launch a new automobile twelve months faster than American firms using traditional methods. This finding spawned a new research interest in time-based competition (Stalk Jr. 1988).

9 Outsourcing to China

As American management learned more about Japanese production systems, it became clear that a stable environment (long-term commitment, job security) was necessary. Trust, teamwork, pride in one’s work, collective problem solving, etc. are essential ingredients to successfully implementing various Japanese production systems. These ingredients posed major challenges to American management. By the mid-1980s, American corporations were not confident that they could compete against Japan with a Japanese-type production system. American managers felt the need to adopt a different operations strategy to compete globally.

By the early ’90s, there were two developments that triggered calls for global sourcing. The first occurred when China opened up various Special Economic Zones, i.e., Pudong (Shanghai), Shenzhen (Guangzhou), etc., and three regions with less “red tape” and more tax benefits to attract Foreign Direct Investment. These zones offered strong economic incentives for American firms to explore the notion of off-shore manufacturing. When deciding whether to off-shore or not, each firm needed to take various types of costs (manufacturing, distribution, transportation, inventory, etc.) into consideration.

To design a global manufacturing network that consisted of manufacturing and distribution facilities in different countries, Cohen and Lee (1989) were the first to develop a global manufacturing network model that incorporated local content requirements, customs, and duties rates, and differential tax rates in different countries. Additionally, Huchzermeier and Cohen (1996) were the first to develop a stochastic dynamic programming formulation for the valuation of global manufacturing strategy options with switching costs under currency exchange rate risk. For a comprehensive discussion about global manufacturing, the reader is referred to the first book on this subject that combined text and cases (Dornier et al. 2008).

While off-shore manufacturing can enable firms to enjoy the benefit of tariff concessions and lower labor cost, Ferdows (1997) argued that such firms are not tapping the full potential of their foreign factories because they can sell into (and learn from) these new markets. It is certainly
appealing to produce and sell different products globally. However, firms such as HP found it challenging to manage inventories where different country-specific requirements prevail (e.g., different languages for labels and manuals, packaging requirements, power supplies, etc.). The problems are compounded by forecasting difficulties.

To overcome such challenges, firms can exploit modular product structure of many products (e.g., electronics, printers, and computers have many modular components). Thus, a firm like HP can keep inventory of partially finished product as generic units and postpone the final assembly process until demand is specific at each global distribution center. Instead of producing a complete product at the factory, HP can customize the generic units into country-specific products at a later point in time so that the “postponement” strategy provides the benefits of risk pooling. However, operating costs (labor, transportation, customs, and duties rates) at different distribution centers can be very different around the globe. As such, careful analysis is needed to determine the best postponement strategy of a product. Lee (1996) and Lee and Tang (1997) were the first to develop models to explain the benefits of the postponement strategy and to determine the optimal postponement strategy under different situations.

When off-shore (global) manufacturing was gaining traction, there was a second development in digital communication abilities in the 1990s, i.e., rapid adoption of digital communication via email, Internet, and mobile phones. These communication technologies enabled companies to manage their global manufacturing more efficiently, which further accelerated the off-shore manufacturing movement. POM became deeply involved with telecommunication technologies (see Chapter 28 in this book).

Off-shore manufacturing and communication technologies created a golden opportunity for the United States to shift from a “manufacturing-based economy” to a “service-based economy” in the ’90s (Karmarkar 2015). Specifically, we witnessed a sea change when companies such as HP began by off-shoring most of its manufacturing operations from the U.S. to Europe (Spain) and Asia (Singapore and Malaysia), and then followed by outsourcing their manufacturing operations to contract manufacturers such as Flextronics who operate heavily in China. By doing so, HP transitioned from computer manufacturer to provider of information technology services.

By the end of IR 3.0, most of the large American firms had become decentralized in the sense that they focused on certain operations (design, R&D, marketing, and sales) in the U.S. while delegating other operations (such as sourcing, fabrication, logistics, and distribution) to other companies. When operating in a decentralized system, most of the POM research literature became less relevant. This is because classic POM literature was developed for centralized planning based on full information and complete control of the decisions for all involved units.

However, in a decentralized system, various parties along the global supply chain belong to different companies, each of which has its own objectives. We know that different parties are reluctant to share their private information truthfully or to cooperate unselfishly unless there are incentives to do so. As such, the wave of global outsourcing created a new incentive for researchers to examine the implications of decentralized supply chains.

In an oft-cited POM research article, Lee, Padmanabhan, and Whang (1997) described the “bullwhip” phenomenon observed by P&G where a minor variability in downstream customer demand can create a huge variability in the order quantity observed by upstream partners along the supply chain. Clearly, the bullwhip effect can cause major inefficiencies in supply chain operations. Lee, Padmanabhan, and Whang (1997) identified four causes of the bullwhip effect. They explained how the identification of these causes can lead to prescriptions for alleviating the detrimental impact of the bullwhip effect. This research article paved the path for many POM researchers to develop ways to mitigate the bullwhip effect.
Lee, So, and Tang (2000) showed that the bullwhip effect can be dampened if downstream partners (e.g., retailers) are willing to share their demand information with upstream partners especially when the underlying demand possesses certain characteristics. The reader is referred to a review of the analysis of the bullwhip effect according to its causes conducted by Derbel et al. (2014) for details.

Intuitively speaking, better communication, cooperation, and coordination among different supply chain partners would be beneficial. However, in a decentralized supply chain, different partners are reluctant to communicate, cooperate, and coordinate unless there are economic incentives. Narayanan and Raman (2004) argue about the importance of incentive alignment among different supply chain partners. To achieve incentive alignment, one party (principal) needs to offer an incentive contract to entice the other party (agent) to behave in the interest of the principal (or the entire supply chain).

Besides mitigating the bullwhip effect and coordinating decentralized supply chains in the 1990s, global decentralized supply chains became more complex, which made them more vulnerable to disruptions with large unanticipated consequences (Craighead et al. 2007). Hendricks and Singhal (2003) were the first to establish the negative impact of supply chain disruptions on a firm’s stock performance. The impact of supply chain disruptions (e.g., Mattel’s toy recalls, Japan’s earthquake, etc.) has led to growing interest in the area of “supply chain risk management.” In a survey article, Sodhi et al. (2012) found that most research articles in this area tend to focus on ways to mitigate supply chain risks and that there is a lack of articles on ways to respond to risk events.

10 Sustainability—Social Responsibility—Crisis Management

Since the early 2000s (IR 4.0), two major forces are pressuring firms to pay attention to the triple bottom line: profit, people, and planet (Elkington 2002, also Chapters 14 and 36 in this book). First, there has been rapid growth in global supply chains (supply) and in global economic development (demand). The demand for natural resources (clean water, crude oil, woods, metals, etc.) continues to rise (especially in countries such as India and China), whereas the supply of these natural resources continues to diminish. At the same time, greenhouse gas emissions have been considered as a possible cause of climate change. This challenge has created a public concern over environmental sustainability.

Second, with growth slowing in developed countries since the recession in 2008, Western companies from the fast-moving consumer goods and other sectors are seeking to expand in emerging economies (Prahalad 2004). However, to develop the emerging market so that the poor producers can become their consumers, these companies need to help the poor to break the poverty cycle. This creates the motivation for companies to embark on social responsibility.

While more companies are developing products with the triple bottom line in mind, Agrawal and Toktay (2010) commented that environmental sustainability/social responsibility remains a nascent research area in the POM literature for the following reasons. First, while there are clear definitions for environmental sustainability (e.g., ISO 14000), there are no consistent measures for social responsibility—despite the newly established guidelines of ISO 26000 (Bloemhof and Corbett 2010). Second, it is challenging to measure a product’s environmental and societal impacts. Third, there are conflicting economic, societal, and environmental factors and objectives of different partners along their respective supply chains.

POM research in the area of environmental sustainability tends to focus on the area of remanufacturing partly because it is directly related to manufacturing even though the flow is reversed.
Ferguson and Souza (2010) compiled an excellent collection of chapters that examine various issues arising from remanufacturing. See Chapter 14 in this book where various issues related to sustainability are discussed in detail.

Another aspect of environmental sustainability and social responsibility lies in the POM field’s response to disasters. POM research on crisis management has grown globally at an exponent rate. The POM Journal established a new Department of Disaster Management in 2014 with Martin K. Starr as its Department Editor. Most POM journals are substantially involved in this emerging arena (see Chapter 29 in this book).

11 What is Next?—Industry 4.0

The Operations Management field has experienced constant evolution over the last 250 years. As we enter the Industry 4.0 era, the rate of change is accelerating. Wikipedia defines Industry 4.0 (or the fourth industrial revolution) as “the current trend of automation and data exchange in manufacturing technologies.” The discussion goes on to describe “smart factories” utilizing cyber-physical systems that communicate with each other via the Internet of Things.

To Wikipedia’s definition, we will add “smart warehouses” and “smart supply chains.” The global distribution network thrives on the ability of cyber-systems to communicate with each other without involving any people. In the background, POM plans, delivers, installs, maintains, and upgrades these cyber-systems. That is “what is next.”

This discussion is meant to assist young and up-and-coming POM researchers to choose optimal career and field-beneficial paths. At the same time that we have lauded flexibility, we have also acknowledged that we cannot predict the future. We do have a better chance of influencing it. In that regard, consider the following three (among many) exciting new POM areas to explore.

11.1 Global Trade Processes

As global supply chains operating in full swing since the 1990s, we observed the number of regional trade agreements has skyrocketed (e.g., NAFTA, Mercosur, ASEAN free trade agreements, etc.). These trade agreements were intended to set up rules and regulations to provide mutual benefits among specific trading partners. As things change, they need to be renegotiated and updated since these trade agreements offer lower custom duties for trading partners but higher duties for non-trader partners. Brexit negotiations represent a case in point.

Hausman et al. (2013) examined how global trade processes affect trade flows between two countries. Their study was based on cross-border trade flows across eighty countries, based on container flows of three specific types of products. The customs differentials among different trading partners with different requirements create a golden opportunity for POM researchers to find ways to design cost effective global supply chains.

To fully exploit the customs differentials of different countries under different requirements, one needs to examine the complete bill of materials of the product and to understand which parts or components will meet certain requirements associated with trade agreements among various trading countries. Finally, it is essential to design a global supply chain network that takes the costs associated with production, transportation, customs duties, etc., into consideration (e.g., negotiations related to TPPs [Trans-Pacific Partnership Agreements]) present another opportunity for POM researchers to examine the impact of TPP on all members of the global supply chain.
11.2 Sharing Economy

By leveraging information technologies (Internet, smart phones, email) that capture real-time data, Uber and Airbnb have disrupted traditional business models used by the taxi and hotel industries. Specifically, these two startups enable drivers and homeowners to earn extra income by driving passengers during their free time and by renting their vacant rooms without incurring large setup costs. By allowing more drivers and more homeowners to enter the market easily, it gives passengers and renters extra options at lower prices.

From the POM perspective, the real-time location data (about the supply of drivers and the demand of passengers) provides a research opportunity to explore how companies such as Uber can develop an effective dynamic pricing model to enable stochastic supply to match stochastic demand. While Uber sets its own price dynamically according to supply and demand, Didi Kuaidi, a taxi dispatching service in China, enables the passenger to set the price for taxi service instead. These two different pricing models raise interesting questions such as which pricing model is better, when, and for whom? As articulated by Netessine (2014), an excellent opportunity exists for POM researchers to examine and evaluate various innovative business models (see also, Girotra and Netessine 2014).

11.3 Data Analytics/Robotics—Phenomenon-Driven Research

Unlike Finance and Marketing, fields that have had an abundance of financial data and purchasing data, POM has suffered from the lack of operational transaction data for decades. With the advancement of information technologies, every company now has access to new forms of data. This gives POM researchers a golden opportunity to conduct exploratory data analysis so as to identify interesting phenomena, e.g., the bullwhip effect (Lee et al. 1997), to conduct descriptive analysis so as to explain certain phenomena (e.g., the sniping effect in online auctions, Ely and Hossain 2009), to conduct predictive analysis so as to improve forecasts (and consequences) of certain events. As articulated by Simchi-Levi (2014), data-driven research enables us to be more creative. POM will play an important role in the development of business analytics (see Chapter 15 in this book). For example, in healthcare, IBM’s Watson supercomputer is scanning more medical records than could ever have been imagined. Computerized scheduling can alter the programs for doctors and nurses and for hospitals and clinics. Great efficiencies are in store (Green 2012).

Robotics will change the equation for out-sourcing and off-shore decisions. The decision mechanism must include a multiplicity of the right factors. POM is in an enviable position to determine the structure of this decision model. Who fashioned it before, during IR 3.0? Finance and Marketing dominated the situation without much consultation from POM. The system is bigger with Industry 4.0.

12 Conclusions

Because so much of POM’s structure was built on the foundation of division of labor and work specialization, it is understandable that POM is a conservative discipline. Caution about change is expected behavior when technology and markets are stable. When this is not the case, a strategy for changing sensibly is in order.

The ability to react quickly with innovative solutions is not what POM teaches nor what it has researched. Disruption is opening up new vistas and great opportunities exist when the stable situation is disrupted. The equilibrium controls must be altered to meet new circumstances (Roth et al. 2016; Starr 2016).
Technology creates market and lifestyle disruptions with such regularity and severity that within any one person’s lifetime, adaptability is essential. Adaptability to extremes may require re-engineering (REE) a system, i.e., making changes starting from scratch. POM did not adapt to REE (Hammer and Champy 1993) during IR 3.0 and preferred to work within the framework of Kaizen (which can be reassuring but misleading). As disruption becomes the “norm,” POM has to learn to anticipate it; if possible, influence its direction; and do more than just cope reactively when it occurs (Champy 1995).

References and Bibliography


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