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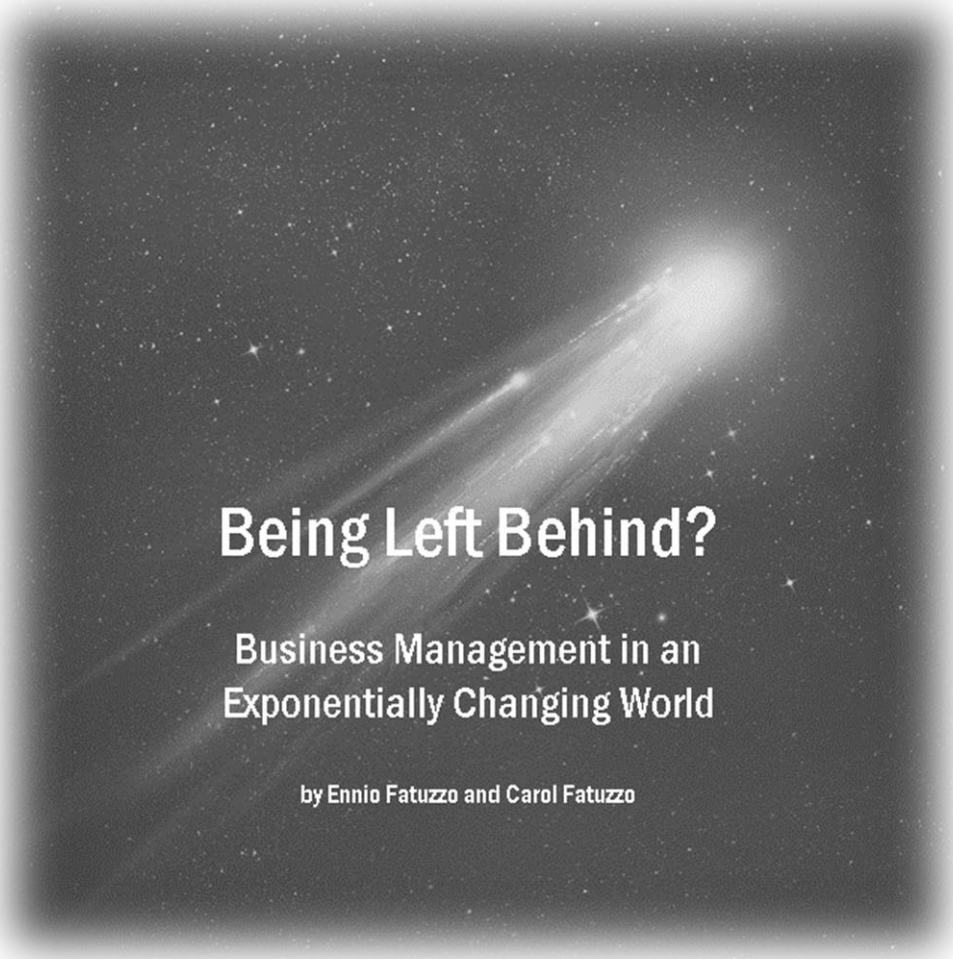

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BEING LEFT BEHIND?

Business Management in an Exponentially Changing World

(Thoughts of business practitioners)

By Ennio Fatuzzo and Carol L. Fatuzzo

Business management is advancing linearly in an exponentially changing, technology driven world and the gap is widening. This is a serious problem for the survival and success of companies in the future. What needs to be done? That is the key question that this article addresses. The answer revolves around the need for the "art" of business management to transition to the "science" of business management. Who can benefit from the article's insights—business leaders who want to prepare themselves for the years to come and teachers of business management who want to prepare their students for the world that sooner or later awaits them.

INTRODUCTION

When thinking about the future of business management, there are three important points to consider: (1) different areas of knowledge normally evolve at different paces, but progress made in one area can often be applied to a slower developing area; (2) today the practice of business management is developing **very slowly** compared to other areas such as microelectronics, and is not showing signs of benefiting from progress in other areas—a situation that needs to be corrected soon; and (3) there are a number of emerging areas in science and technology where **substantial** breakthroughs are possible in the longer term (say the next 10 to 30 years), and these might provide business management with opportunities to "ride on their coat-tails" to accelerate the change from management as an art to management as a science.. But 10 to 30 years is a distant future for most businesses.

Business management is moving linearly in an exponentially changing world.

What can be done in the meantime to start fueling a business management revolution? To address this we provide examples and our assessments of what we believe to be the most usable and progressive forms of business practices and methodologies that are available **today**. These are the first steps towards practicing business management as a science instead of an art.

To make our case, the article is divided into four Parts. **Part I** reviews the evolution of technology, in the recent past and present, as a backdrop against which to compare progress in business management. The technology focus is the explosion of microelectronics (specifically integrated circuits) and software that are dramatically changing the world. **Part II** then addresses typical business management and what

we call "strategic governance" of many of today's companies. It shows why today's approaches impede fast progress in the development of urgently needed new business practices. **PART III** focuses on near-term (1 to 3 years) possible and necessary changes in business management. It champions the use of advanced analytical methodologies for rapid and effective decision making and addresses related leadership issues. **Part IV** highlights several areas where revolutionary advances in science and technology could be game changers for business and business management. These are not meant to be predictions of the future, because, as we show, most past predictions of the future have been far off the mark. So, instead we attempt to identify some avenues along which there may be a "dark horse" that catapults companies and business management into the future.

Bottom line, many new technologies are constantly being created, and some end up propelling the world forward with ever increasing speed, for years and years. Such technologies are having and will continue to have dramatic impacts on business as we know it. So the question is how does business management keep pace with current, rapidly developing, high impact technologies, and be in position to ride on the coat-tails of what comes next? It's all about disruptive science and technologies. Hence we start by discussing the key ones of yesterday and today, and exploring the differences.

PART I: THE MICRO-ELECTRONICS TECHNOLOGY REVOLUTION

1. TECHNOLOGY-BASED REVOLUTIONS: A BRIEF HISTORICAL PERSPECTIVE

To better understand the impact on business of today's Micro-electronics technology revolution and to make realistic projections about the future, it's important to explore how science and technology evolved in the relatively recent past. Then it is possible to answer the question: Is the rate of change of micro-electronics technology the same as that of revolutionary technologies in the past or is it different? The answer to this question determines the consequences—for the world in general and for business management specifically.

Of course, technology revolution is certainly not new. Since the beginning of human civilizations, there have been many technology-driven revolutionary changes. Early examples, as early as prehistoric times, are the inventions of fire-making and of the wheel. However more recent technology revolutions are more relevant for our purposes. We start by taking a quick look at the Industrial Revolution.

Today, in industrialized nations, products are manufactured swiftly by the process of mass production, on assembly lines, using power-driven machines. People of older times had no such products or systems. The Industrial Revolution is the name given to the collection of technology-based inventions which enabled this current way of life. The key driving forces for this revolution were (1) the invention of machines to do the work of hand tools; (2) the use of steam, and later of other kinds of power, in place of the muscles of human beings and of animals; and (3) the adoption of the factory system.[1]

Starting in the 1700's, and continuing through the early 1900's, this technology-driven revolution was characterized by things such as the building of railroads, large scale iron and steel production, widespread use of machinery in manufacturing, steam engines, electricity, and the coming of age of oil. These disruptive developments totally changed the way of life of large masses of people, but took over two centuries to evolve.

Moving ahead to the early-to-mid 20th century, the invention of the vacuum tube and its impact on telecommunications and the birth of

companies like RCA, based on this original invention, led to the era of electronics, in general, and consumer electronics specifically. Again this is an example of a technology revolution that has had and continues to have a very large impact on our way of life and the way we do business. And this time the revolution only took a few decades.

2. *THE CURRENT MICRO-ELECTRONICS TECHNOLOGY REVOLUTION: INTEGRATED CIRCUITS.*

Clearly, some basic inventions have long-term consequences radically different from others. Some are like cannon shots that cause great turmoil, but are not followed by a "tail" of progress on many different fronts. Such cannon shots awaken people to new, albeit constrained horizons, and then leave them free to explore new areas of technology, but only **within those horizons**. However, other types of basic inventions involve technologies that keep propagating, and have an effect more similar to that of **a rocket with continuous propulsion**.

Some basic inventions have long-term consequences radically different from others.

The technologies of the Industrial Revolution (power first from steam, then oil, then electricity) are examples of multiple "cannon shots" of their times, while the vacuum tube exemplifies a specific "cannon shot." But micro-electronics technology, in the form of integrated circuits, is a rocket of today. Why do we say that?

In the late 1960's and early 1970's, a soon to be world-changing event occurred—the invention of integrated circuits. An integrated circuit (also referred to as an IC or a microchip) is a set of electronic circuits on one small chip of semiconductor material, normally silicon. The packing density of these electronic circuits on a single chip directly impacts their capabilities, and the packing density has been doubling every 24 months for the last 40 years! (Moore's Law). The impact of this doubling is the same is as if a major new invention was being made every 24 months, and this has been going on for the last 40 years! Doubling every 24 months means **growing exponentially**. The overall impact of this ever increasing rate of growth MUST be different than the impact of one-time breakthroughs, no matter how revolutionary they are. And in fact it is this exponential increase in integrated circuit capability has led to an explosion of new ideas and an unparalleled environment for creativity. And in turn this has led to the creation of many new products and companies based on these ideas. Already this integrated circuit based revolution has radically changed the world as we know it.

However, the mushrooming impact of IC's isn't quite that simple. A lot of the science and technology-based progress made after the original invention was due to unleashing the collective power of innovation by making each new IC "invention" (generation) immediately and easily accessible for many other people who then provided a number of secondary inventions and thus multiplied the effect of the first. Examples are numerous and include diverse things such as 3D printers using advanced computer capabilities; ANSYS engineering simulation software for personal computers, and the internet itself.

And the impact of IC's is just beginning. Think about what it means to grow exponentially, like the performance of integrated circuits. For example, imagine that 40 years ago, you saw a small centipede in your home. Say that it was one inch in length. No big deal. You could have squashed it with your shoe. But imagine now that you let it live, and the centipede grew with the same exponential law as the performance of integrated circuits. The same centipede would now be 200 miles long. Impossible to squash

with your shoe. Now imagine that it keeps growing for another 40 years at the same rate. The centipede would be larger than the earth, so large that it would be impossible to control.

Such continued exponential growth in IC capabilities is forecasted by some. If this happens, are we still going to be the masters of the technology or are we going to be its slaves in an unimaginably changed world? This is a particularly important question for business management that already is being left behind. To address this issue it is important to start taming this technology beast NOW, when it is still manageable. And the first step is to look at examples of the mushrooming impact of integrated circuits.

3. *PRODUCTS AND RELATIVES OF INTEGRATED CIRCUIT TECHNOLOGY*

In the field of communications, the consequence of the Moore's law growth in IC capabilities has been to originate, with the impetus from visionaries like Steve Jobs, an astounding series of innovative products such as the flat screen TV's, smart phones, tablets, wearable computing devices, and more. Just think about it. Today a smart phone like the iPhone, in addition to cell phone capabilities, has computer capabilities similar to those of large mainframe computers of 30 to 50 years ago.

But take a step back. A broad reaching development, interwoven with the advances in integrated circuits, is the cell phone (followed by the smart phone), a capability that has spread with lightning speed throughout the world—fueled by the availability of small, low cost, reliable devices and the expanding reach of cellular networks. And of course there is the world-changing Internet and its rapidly expanding global reach. Ten years ago, only 12% of the world's population used the Internet. Today, that number has grown to almost 40% (77% if you consider only developed countries).[2]

Communication, ready access to information, new ways to teach and learn, e-commerce—the list of its uses goes on and on. Today the Internet is an integral part of everyday life and business, but who would have imagined any of this just 25 years ago? And it would be impossible without the ever-changing integrated circuits and the advanced computer related products they enable.

Every day brings new capabilities, fueled by advances in Integrated Circuits.

But cell phones and Internet are only a start. Social media, a software-based child of the union of cell phones and the Internet, has had a huge impact across the globe. Today almost half the population of our planet can instantly communicate with each other through social media such as Facebook or twitter or.... These powerful, multi-way communication "tools" have already had important political implications, such as enabling the insurgences in the recent "Arab Spring" and supporting the more recent riots in Hong Kong. Every day brings new capabilities, fueled by advances in integrated circuits.

One final example also enabled by the IC revolution, but perhaps a technology-based revolution on its own—the explosion in the science of algorithms. Progress in the development of algorithms has occurred even faster than in integrated circuits. In his article in *The Economist*, Ryan Avent writes: "Between 1988 and 2013 the effectiveness of computers increased 43 million-fold. Better processors (integrated circuits) accounted for only a minor part of the improvement. The lion's share came from more efficient algorithms." [3] Some consequences: significant increases in capabilities of search engines such as Google; driverless cars which were thought to be

impossible by experts just a few years ago; drones; more and more sophisticated "apps" for smartphones and tablets; and more.

But the IC revolution is still young. The question therefore is: What will the world business be like 5 years from now or 50 years from now? And what about business management and business practices? Already an astonishing stream of new products, new companies, and new capabilities has been born as a result of the IC revolution. But business management is much the same as it has been for many years, and that's a problem for future company survival.

PART II: TODAY'S SLOW EVOLUTION OF BUSINESS MANAGEMENT AND "STRATEGIC GOVERNANCE"

1. BUSINESS MANAGEMENT

In the past, and not all that long ago, business management evolved slowly, as did the world around it. The pace of change was slow everywhere, so everything stayed "in sync." However today, business management is surrounded by the effects of the rapidly increasing rate of change. Specifically, the micro-electronics technology revolution has brought about unsurpassed speed of calculation, unbelievable speed of communication and unimaginable capacity of memory systems—all capabilities that should be very important in business. These capabilities have created a world far different from, and much more interconnected than what had existed before, or had ever been dreamed of.

But what has happened to **business management**? How has it changed to adapt to and take advantage of today's rapidly changing world? The answer to both questions is NOT MUCH. In the words of Gary Hamel:

"When compared to the momentous changes we have witnessed over the past half century in technology, lifestyles and geopolitics, the practice of management seems to have evolved at a snail's pace."[4]

In other words, the micro-electronics revolution has not yet resulted in a revolution in business management. In this part, as a first step towards understanding why, we explore and critique typical business management of today. The main point we make is: What is being taught in many business schools and by many consultants (and therefore being commonly practiced) is an "old" type of business management which is not projected toward the future.

To illustrate the "typical" way business management operates (and is commonly taught in business schools and by consultants), we provide the following example. Although this example is not terribly recent, it is still relevant since business management is evolving so slowly (as can be seen from many of the business books published recently).

Now, the example. In July 2006, prior to the most recent economic recession, there was an interesting article was published in *Fortune* magazine by Betsy Morris.[5] Jack Welch, the legendary CEO of General Electric turned "guru" after retirement, had spoken widely and written about his management rules for business success, at least for his company. Welch's rules, as listed in Morris' article, are:

1) Big Dogs own the Street
2) Be No. 1 or No. 2 in your Market
3) Rank your Players: Go ahead with A's
4) Shareholders rule
5) Be Lean and Mean
6) Hire a Charismatic CEO
7) Admire my Might

However Morris considered Welch's rules to be obsolete. The "new" rules proposed by Morris to replace the "old" ones were:

1) Agile is Best; Being Big can Bite you
2) Find a Niche, Create Something New
3) Hire Passionate People
4) The Customer is King
5) Look Out, Not In
6) Hire a Courageous CEO
7) Admire my Soul

In the article, Welch's reply to Morris was that some of her "new" rules were consistent with his "old" rules. So he agreed with those. However for the ones that were not, he strongly disagreed. For example, in support of his rule No. 3 (weeding out the weakest employees) versus Morris' "hire passionate people" rule, he noted: "The Red Sox and the Mets are playing tonight. Guess what? They are fielding their best team."

Going back to Welch's "old rules" and Morris' "new rules" in general, there is the issue of whether these rules are meant to have a short-term or a long-term effect on financial results. This is left somewhat unclear in the debate, so contributes to the difficulty in judging who is correct—Jack Welch, the experienced retired CEO of a very large company, now a top consultant to many diverse corporations; or Betsy Morris, the business journalist without direct experience in managing a large business?

In a sense, one can say that both are right and both are wrong, depending on the definition of business success, the timeframe being considered, and your view of business management. For example, if you "manage by words" rather than "managing by numbers" the above "rules" are compatible for the most part, and both are right. The trouble is that today's stockholders are not interested in "words". They are interested in immediate results measured by numbers such as sales, sales growth, Profit & Loss, Return on Capital, Return on Equity, etc. And without stockholders' confidence, a company cannot do well. Therefore, from this view of business success, it is essential to "manage by numbers." And in this case both Welch's and Morris' rules are wrong.

As early as 1994, this "words" versus "numbers" issue in business management was recognized. Consider the short article written by Maurice Ramsey,[6] a then retired senior lecturer in physics at Northumbria University in the UK. In this article he described the three main activities of the "education establishment," which he called the "three cultures". Examples he gave of these "three cultures" were: (1) scientific (e.g., the Schrodinger equations), (2) artistic (e.g., one of William Shakespeare's sonnets), and (3) business management (an area where there are no specific examples because teachings are only expressed in general words). His conclusions about this "third culture" are rather harsh. He writes that: "The third culture seeks not to enrich and enlighten but to control and self-propagate." And he posits that the "words only culture" is one that is often propagated by business consultants.

The challenge for business management is to bridge the gap between words and numbers.

The point we are making with these examples is that in today's radically and rapidly changing environment, where speed, adaptability, and accuracy are keys to business survival, one cannot manage a company by basing actions ONLY ON WORDS. Yes, today the final objectives are always stated in numbers, but only words are used to plan how to get there. In our fast paced, technologically driven, exponentially changing world, the challenge for business management is TO BRIDGE THE GAP BETWEEN WORDS AND NUMBERS—to **manage,** not just measure, the business by

numbers. Please note that we said "manage the business" (which includes strategy building and decision-making) and did NOT say "manage the employees," which is a very different proposition.

In conclusion, while the world is radically changing, business management is not proactive in coping with these changes. In other words, business management is NOT keeping pace with the technological and economic realities of the times. Common business management practices are no longer adequate for coping with today's world. Bottom line, **business management today is obsolete.** It is being practiced as a slowly developing "art" or (even worse) guided by fads that come and go**,** devoid of major, permanent leaps.

So, where do we go from here? There are some very interesting attempts to bridge the gap between words and numbers. A concept which is very fashionable today is that of analyzing "big data" (collections of data too large and complex for traditional processing). However use of "big data" has limitations, as became clear when it was attempted to use this technique for the prediction of the spreading of Flu viruses.[7]

Business Management today is obsolete.

In short, "big data" analyzes the past in order to try and predict the future. Not a good process when the future changes exponentially and many different factors affect this evolution! But it is a start at transitioning business management from an art to a science, and thus will be addressed in more detail in Part III.

2. *TYPICAL COMPANY "STRATEGIC"GOVERNANCE TODAY*

Much of the fate of a company is determined not only by external forces, but also by the management processes adopted by the company, in other words, by what we call its "Strategic Governance." By this term we mean the processes by which important strategic decisions are made and the individuals or groups of individuals who have the power to make them. In other words, "Strategic Governance" defines who makes the decisions about the future direction of the business and how those decisions are made.

Too often today a CEO "inherits" a type of Governance when he/she is elected by the Board, and keeps everything the same. However in a rapidly changing environment, a new, adaptable and more streamlined approach is often necessary for survival. Therefore in this section we discuss and critique three aspects of typical Strategic Governance of companies today: shorter term focus, risk avoidance, and decisions by committee.

We are sure that most readers are somewhat familiar with the typical organizational structures of most mid to large size companies, so we will not discuss them in detail. Suffice it to say, most companies are organized into three or four main Functions, commonly reporting to General Management or the President. These functions usually are Manufacturing (where applicable), Sales and Marketing, Research and. Development (R&D), and Quality. The main operational focus in the business conduct of these functions, and of the company as a whole, is to reach specific objectives related to the financial performance of the company. These objectives are mostly connected with short to medium term profits and revenue growth. Company survival and success in the longer term is of course very important, but in today's economy many executives mistakenly believe that this is fairly assured if the shorter term financial objectives are achieved.

As the result of this shorter term focus, the main goal of corporate management (and thus functional management as well) in many mid-sized and large companies today is to avoid actions that can harm the profitable growth of a

company in the shorter term. This leads to risk avoidance by those in charge since an executive or a lower level manager can lose his or her job if things go wrong or a perceived mistake is made (say a bad investment or an acquisition that doesn't live up to expectations. In other words, if the business takes a downturn or a particular financial objective is not met, even when the a-priori conditions appeared to be very favorable, by definition it is **always** a mistake.

But this low risk approach to business has a significant downside. Big rewards often involve big risks. By avoiding risks, large opportunities are likely to be lost. Just consider companies like Apple, Facebook, and Amazon. They have taken and continue to take big risks (e.g., new technologies, new business models, whole new businesses), and their rewards have been huge!

And risk avoidance isn't the only problem. Another, extremely common way that today's management avoids responsibility for mistakes is by diluting responsibility for decisions. This is done by the broad use of "decisions by committee" at all levels. This practice is often promoted as a way to achieve more effective teamwork and to make better decisions, but it has another attribute. If a decision has a bad outcome, the main fault becomes that of the deciding group or committee. The days of "the buck stops here" in senior management are vanishing into history.

But spreading responsibility for actions isn't the only issue with "decisions by committee." A group usually tends to adopt the view of its more "conservative elements", thus further minimizing risk at the expense of potential maximum reward. And although it is unclear whether decisions turn out to be more often "correct" when made by a committee, it is certain that they are slower. Why is this? A typical corporate decision-making committee takes time to assemble, and frequently—due to busy schedules—only meets once a month. Often the committee does not approve the proposal right away, but wants to see revisions that take time to be made, say another month. Then, a month later, there is another presentation to the committee; and, with luck, the proposal gets approved. And often it is not clear that this proposal is improved with respect to the original one. Although in some types of organizations the time it takes for decision-making may be less critical, in a fast-paced world with aggressive competitors, rapid decisions are essential for business survival. In other words, a slow decision is always a wrong decision.

A SLOW decision is always a WRONG decision.

However, it is important to keep in mind that sometimes there is a need for "decisions by group." With the increased complexity of business in our rapidly changing world, there is often a need for many different types of expertise to be brought to bear on problems and decisions. The challenge is to reconcile the need for speed with this group approach to complexity. This will be addressed in Part III.

PART III: BUSINESS MANAGEMENT—THE NEXT STEP

1. *TOOLS AND METHODOLOGIES AVAILABLE TODAY, BUT NOT WIDELY USED*

In this section we focus on computer-based methodologies that could be used today, but often are not—specifically computer assisted business optimization and more advanced business analytics and big data. Although there have been promising developments in Game Theory and ABMS (Agent Based Modeling and Simulation), we believe that these approaches are not yet practical for broad business use. Therefore we

address them in the next section (Tomorrow's Business Practices).

Computer Assisted Business Optimization

Cost cutting, pricing optimization, sales promotions, new products, new businesses, new strategies, new… What is the right mix of actions and directions for a business? That depends on business performance and objectives, and those depend on many interrelated variables. For example, pricing, advertising, product quality, and competitive position all affect sales; and sales affect manufacturing utilization which affects costs. And of course profits depend on sales and total costs. And what about cash flow? This extremely important business metric depends on many variables—income, depreciation, investments, inventories, receivables, accounts payable and more.

As one can see, it is not straightforward to optimize a business in order to obtain the best results for the objectives identified as most important by the CEO. Too often business management focuses on a single, easily identifiable and changeable factor (e.g., pricing), and actions are taken based on "what if" scenarios created using simple spreadsheets. Then the focus moves on to the next single factor. Yes, that could be called computer assisted business optimization, but it is extremely limited.

But a relatively simple computer model can do better. How do you proceed if you want to develop such models? In our book *Survival in the Sea of Economic Chaos*[8] we provide several examples, limited in scope but better than a single variable analysis. In one case, the dependence of units sold (and hence sales) on selling prices is plotted using the price elasticity of demand, (determined from separate studies). Another example models the effect of selling prices on profits by incorporating a plot of costs versus units produced.

However the relatively simple models described above still do not take into account many other relevant, interrelated variables. Furthermore, measures other than profit sometimes can better represent a company's financial performance. For example, return on assets can be more important in the case of the grocery stores business. Or accurately determining cash flow may be essential when there is the possibility of a shortage of cash or excessive up-front investments have been made.

In these cases, simple calculations are not sufficient and a computer model better representing the **whole business** is preferable and possible. But developing such a model requires some programming expertise. Variables needing to be incorporated into the model include:

- those which can be assessed by appropriate market research (e.g., expected sales volumes, price elasticity, cost and effectiveness of advertising and promotion)
- those which can be determined by appropriate internal audits (e.g., fixed and variable manufacturing costs; the probability of success, the **returns,** and the **timing** of both R&D programs and manufacturing/process improvements

Although it is desirable, one can see that the effort in producing a complete computerized model of a company's business is quite work intensive. In practice, only a mid-sized or a large company may be able to afford it. For smaller companies we suggest that the examples referenced in this section and illustrated in more detail in our previously referenced book (Reference 8) would be a good starting point. However to be competitive in the near future, companies of all kind and sizes will need to have business intelligence systems and expertise to drive reporting and descriptive analytics and to embrace "data science" as described in the

following section on business analytics and big data.

Business Analytics and Big Data

Business analytics refers to "the extensive use of data, statistical and quantitative analysis, explanatory and predictive (computer) models, and fact-based management to drive decisions and actions." [9] The rapid development and adoption of advanced business analytics technologies is already altering the business landscape.

As mentioned previously, **Big Data** refers to data sets too large for traditional data processing. These data sets have the potential for "huge new benefits—but also heartaches."[10] The explosive emergence of such huge, fast-changing, unstructured data from various and new sources, mostly external to a business, and attempts to analyze them, has created the "age of information"—an age where knowledge is power.

Now combine "big data" with advanced analytics. Unparalleled and real-time access to vast quantities of data and the ability to rapidly analyze them in meaningful ways are already realities. What we are talking about is the rapidly growing capability of harnessing the vast potential that is hidden in multiple sources of massive data/information.

Today many companies already are analyzing "big data" to achieve significant competitive advantages—to improve products and services, cut costs, attract repeat customers, and more. An IBM Global Business Services Executive Report documents several big successes: "Companies like McLeod Russel India Limited completely eliminated systems downtime in the tea trade through more accurate tracking of the harvest, production and marketing of up to 100 million kilos of tea each year. Premier Healthcare Alliance used enhanced data sharing and analytics to improve patient outcomes while reducing spending by $2.85 billion. And Santam improved the customer experience by implementing predictive analytics to reduce fraud."[11]

Still embryonic though, are advanced analytical methodologies that can be applied to "big data" to build useful models for predicting and optimizing future outcomes. Such tools would enable leaders to make better decisions and make them faster. This is the promise of the emerging field of data science[12]—the marriage between "big data" and "advanced analytics," the former providing the information, the latter supplying the tools that can be applied to that information to develop insight and guide action. However, there is one giant caution for business leaders. Big data and analytics, no matter how sophisticated and expertly used, won't replace or necessarily even predict disruptive innovations. Analyzing the past and extrapolating to the future is not likely to accurately predict a future shaped by unparalleled change.

***One giant caution**: Analyzing the past and extrapolating to the future is not likely to accurately predict a future shaped by unparalleled Change.*

2. TOMORROW'S BUSINESS PRACTICES

We advocate a greater use of scientific methodologies in business management, especially for developing new and better strategies and plans. To be more specific, today data on the PAST performance of a company usually is analyzed in great detail using some form of business analytics. Common examples include the Profit and Loss statement, the Balance Sheet, and analyses of Cash Flow and Return on Investment. And, more recently, as described in the last section, computer analyses of "big data" are becoming common as the field of data science develops. **But these all are**

analyses of the past—past data, past performance.

When it comes to projecting alternative possibilities for future performance in a rapidly evolving and competitive world, different tools and methodologies are necessary, tools like Game Theory or ABMS or something not yet invented. Although these tools have not yet been developed to the point where they are readily usable and reliable enough for broad applications, we describe them in this section. Why? Because we are confident that these and/or related technologies will be developed in the near term that will give management the ability to simulate electronically the alternative future performance of a specific business, including its financial results, when different strategies, tactics, and competitive actions are imposed on the company.

Game Theory

Game Theory is an example of one powerful science-based approach that can more accurately evaluate alternative "futures." It is a branch of applied mathematics which is used in economics, biology, computer science and other disciplines. It attempts to mathematically model behavior and predict results in competitive situations, where the outcomes of an individual's choices depend on the choices of others. It was initially developed to analyze competitions where one individual does better at another's expense (the so-called "zero sum" game), but has been expanded to other competitive and/or cooperative situations.

This methodology, when applied to business, creates a "game" that consists of: a set of "players" (competitors), a set of "moves" (rational actions) available to those players, and a mathematical model that predicts the "payoffs" that players might receive for each combination of actions. By "playing" this game, a leader can evaluate possible alternative outcomes of encounters with competing organizations that may have parallel and/or conflicting goals. In other words, Game Theory can help leaders make better strategic decisions in complex situations by predicting the probable consequences of the collective actions and reactions of all the players.

The basic principles of Game Theory can be applied **qualitatively** to provide general guidance, but a full **quantitative** model is needed to predict outcomes in the complex and dynamic economic environment of the post-recession world. However, this is not simple. Developing accurate models requires the use of advanced mathematical tools that are not common knowledge among business leaders. Therefore leaders must find and rely on appropriate experts for model development and application (game playing). Even though this approach is complex, it can be worthwhile for a large company or a complicated business situation.

Game Theory is particularly useful for exploring alternatives when there are multiple players, conflicting goals, and many action options. However, one should be cautious. The more complex the business situation, the more complex the mathematics are. In addition, Game Theory assumes that the players always make **rational** choices, and that doesn't always happen in the real world or business. Bottom line, Game Theory can be a useful tool. However, it takes investment—in time and in people. The good news is that there are a number of consultants and experts available who have experience in successful business applications of this methodology. The hope is that future developments will make this more readily useful to the broader business management community.

For more detailed information and references on Game Theory, see our article "Science-Based Decision-Making."[13]

Agent Based Modeling and Simulation (ABMS)

Although Game Theory provides an excellent logical framework for simulating business situations, the complexity of the real business world makes the development of rigorous models difficult. The decision-making methodology highlighted in this section, Agent-Based Modeling and Simulation (ABMS), is a science-based tool that takes a different approach.

ABMS is a computer-enabled methodology that describes (and predicts) the evolution of dynamic systems by simulating the behavior of their constituent "agents" (individual parts or players). In other words, ABMS is a modeling technique that rapidly converts knowledge of a large number of individual behaviors into an understanding of overall system-level outcomes. To do this, it combines elements of Game Theory and complexity science, and uses Monte Carlo methods to introduce randomness.

More specifically, with ABMS, a system (e.g., your market) is modeled as a collection of entities called Agents. Each Agent individually makes decisions and acts based on a set of rules appropriate for the system it represents (e.g., producing, selling, buying). ABMS can create thousands of individual Agents rapidly, and it allows "learning" and repetitive interactions among those Agents to occur. This enables the system to evolve and unanticipated behaviors to emerge (emergent phenomena). This adaptive feature allows ABMS to explore complex system dynamics which are out of the reach of the pure mathematics of Game Theory. In other words, ABMS has the ability to predict potential outcomes such as market shares, sales, and profitability and to provide strategic insights into future marketplace behavior.

To summarize, the key features differentiating ABMS from Game Theory are: 1) it builds the market (predicted outcomes) "bottom" up from many individual interactions, 2) it can use data in many forms from many sources, 3) it can analyze multiple scenarios rapidly, 4) it does not require rational actions and allows for adaptive behavior, and 5) it produces unanticipated emergent phenomena. Thus, ABMS is an excellent science-based methodology to help leaders make decisions about problems with many interrelated but unpredictable elements. However, it is important to keep in mind that models, no matter how sophisticated, can only project probable outcomes, not actual reality. Therefore it is up to the decision-maker to use those projections wisely. In addition, like Game Theory, ABMS also requires investment and expertise.

Again, for more detailed information and references, we suggest our article "Science-Based Decision-Making" (Reference 13)

Other Science-Based Possibilities

Game theory, ABMS—the direction is right, but why aren't these techniques used more often and **more successfully** in many more companies? It is interesting to note that many consultants who organize many well-attended courses for managers seldom list Game Theory and ABMS among the subjects they treat. Is it because they are not useful in practical management? Or is it because they are too complex to teach in a seminar or too complex to use effectively?

Some progress is being made that addresses these concerns. For example, IBM is offering a service which they call the "IBM Watson Engagement Advisor."[14] As IBM describes, this service combines the basics of "big data" handling with the Watson technologies of natural language-based processing, hypothesis generation, and evidence-based learning. The result, they claim, is that a business manager who is not a statistician or data scientist, can type in questions to probe/analyze corporate big data in meaningful ways. In their words, business professionals can quickly understand and make decisions based on Watson Analytics' data-

driven visualizations. For example, one might ask and get a data-based answer to the question "What high-value customers am I most likely to close sales with during the next 30 days?"

If IBM can already do this, perhaps they will soon be able to expand their technology to include **easy-to-use** capabilities for accurately projecting business futures based on data and alternative strategies and actions. This is just one possibility. In our technologically driven world, we are confident there will be other data science developments in the not too distant future that will provide new science-based capabilities for better business management.

Computers are great—when there is enough human supervision.

However, before relying entirely on computers, some caution is needed. Remember that the 2007-2008 financial crisis was due to excessive reliance on computer programs. Computers are great—when there is enough human supervision; but otherwise, managers beware.

3. *CEO RESPONSIBILITIES—NEW DIRECTIONS*

So far we have advocated the increased use of science-based methodologies as the "next step" in business management. This we see as key in transitioning business from an art (as it is practiced today) to a science (as it must be practiced tomorrow). And this important but difficult transition must be championed and driven by whom? By the CEO who must explain it, "preach" it, and **order** it to the personnel of his company. He/she is the one who must make these and other changes happen.

However, this isn't enough. The role and key responsibilities of the CEO also need to change. We address what we believe are essential changes in two key areas—establishing overall corporate direction and strategic governance in the next two sections.

Corporate Direction

An important, but not new responsibility of the CEO is setting the corporate financial goals and business objectives. Typical financial goals that could be established include sales, profits, cash flow, return on assets or capital employed, and earnings per share. Business objectives might include growth, market share, new products, green products, etc. In the past, it was relatively simple: establish a goal, develop a strategy (usually qualitative), and then implement that strategy. Then, repeat the process for the next goal.

However establishing goals and objectives is no longer simple. Everything is becoming interconnected and more complex in today's shrinking world. Goals, objectives, strategies and external forces (e.g., competitive, economic, and political) are intertwined and interdependent. Is it growth in sales or profits, or can it be both? What balance of risk versus reward is acceptable, over what time period? What is the best target market, and should the focus be high volume or niche? What will be the impact of changes in the economy? And what about global competition, both direct and indirect? And the list of issues to address goes on.

Bottom line, today the key question is: Are the **combination** of goals and objectives realistic and attainable with the chosen strategy? Well, that depends—on the business definition, business model, competition, access to products and technologies and... Bringing all of this together and optimizing the total package in a way that leads to business success is the challenge that faces today's CEO's.

This challenge isn't new, but in a chaotic and rapidly changing, global environment, the complexity of addressing this challenge is

increasing exponentially—just like technology. So the qualitative approaches of the past are no longer adequate. However there is an important new development: the growing ability to quantify the outcomes of combinations of alternative choices through the use of advanced computer models of the business and market in question. By adjusting the relevant parameters for each combination of choices selected, different alternative futures can be compared.

Ultimately, and in the not too distant future, with the proper, easy-to-use software, the CEO will be able to adjust the goals and determine the best strategies by having "war games" played on computers in a match among competitors. Such a process will project business outcomes, answering questions such as: Which strategy (including business definition and business model) will lead to a major market share, or provide the highest profits over several years, or produce the most rapid increase in sales, etc. However, to realize the full potential of new science-based methodologies, CEO's must moderate their mostly intuitive approach, and embrace a quantitative future. In other words, a CEO must become as skilled in analyzing numbers as he or she is in using words. Or, alternatively, he or she must rely on a high level corporate expert.

Strategic Governance

It used to be sufficient for the CEO to examine the market, choose the business goals and objectives, and then select the best strategy. These types of responsibilities (still important) were addressed in the last section where we discussed how carrying them out needs to change.

However, there are other leadership responsibilities that have increased importance in the 21st century. Today and in the near future, one of the most important jobs of a leader is choosing the best type of what we are calling strategic governance for his or her corporation. This responsibility has rapidly increased in importance because of the new types of strategic governance that are emerging in very fast-growing and successful companies.

For example, take a look at some of today's high visibility, "super-growth" companies—companies such as Apple, Facebook, Amazon, and Google. Two common factors that link these companies together are the overwhelming presence and power of the Head of the company and, presumably, limited **strategic decisions** by committee. The Head decides. What are the advantages? Very fast decisions and changes of direction that can result in very fast growth! And what about the disadvantages? Simply stated, the biggest disadvantage is RISK—risk of poor decisions, unwise directions, alienation of personnel. A solitary decision-maker increases such risks but also offers the possibility of huge rewards. Both must be accepted as part of this type of strategic governance. However even these "super-growth" companies have not always found the best combination of speed versus risk. We believe that finding that optimum balance will require a much heavier reliance on advances in data science, and yes, even committees.

What specifically do we mean? In a complex business environment, radically different strategies and good decisions are likely to require input from a number of different experts. How can this be reconciled with the need for speed? We believe this can be accomplished by separating the collecting and analyzing of data and the developing of possible alternate decisions from the decision-making and execution of the final choices. The first can still be done by assembling a diverse committee with the needed expertise. The role of this, by nature somewhat slow moving group, is to provide and analyze data and simulate and compare different scenarios and possible alternatives using suitable computer-based technology. Thus this committee can make useful recommendations for the

possible courses of action in a reasonable timeframe. Then the leader (CEO) makes the final decisions on strategies and actions based on the best data available, and he can make them very rapidly when needed.

Of course this approach is not a guarantee of success. For example, if a CEO misjudges the market or picks the wrong technology, no strategy is likely to work. But the use of advanced computer modeling can greatly improve the probability of success with respect to where it is today. Bottom line, a powerful leader who establishes a strategic governance suited to using powerful science-based methodologies is positioning his or her company for future success.

One final note. This section has only addressed the needed changes in the top management of a company. Such changes also require changes in the organizational culture and its structure (e.g., R&D, Manufacturing and Engineering, Marketing and Sales, Quality). They also create the need for a new function based on data science and new business processes to be used throughout the organization. Championing and implementing these types of changes in governance is also an important new responsibility for the CEO. However they will not be addressed in this article.

4. THE RISKS OF CHANGE: AN EXAMPLE

Simply, our main message in this article is that business management needs to change and change NOW—from management as an "art" to management as a "science." However, such radical changes are not without risk. As a caution, we provide the example of RCA—in its time a "superstar" company with a powerful Head, but now dead and almost forgotten as a company.

Business management needs to change and change NOW—from management as an "art" to management as a "science."

The RCA Company (Radio Corporation of America) was founded by General Sarnoff and grew to be one of the world's largest corporations in its time. And, not too long ago, it was very difficult to imagine the downfall of such a powerful symbol of the technological revolution that began at the start of the 20th century. But now, the name RCA is only a trade-mark. What happened?

Once upon a time, RCA was a large and vibrant manufacturing company whose world-class laboratories invented and commercialized many disruptive new technologies. The company used these radical innovations to reach great heights of success. With its revolutionary radio and television products, RCA even created a new industry (consumer electronics). The company (and its leader) perceived itself to be invincible. But it wasn't.

The drama of Video Recorders, as summarized here from our article "Video Recorders—A 'Killer' Tsunami,"[15] explains its downfall. It is the final episode in the story of RCA. It is a story about business leadership in the presence of giant waves of change that irreversibly altered the business landscape. These disruptive waves brought both destruction and opportunity to the companies involved.

In the early days, RCA benefited from the very strong leadership of General Sarnoff. He was a visionary leader who identified, without market research, three ideas that in quick succession had great successes and won the marketplace: radio, black and white television, and color television. But later Sarnoff pursued opportunities in other unrelated areas, such computers, where he tried to compete with IBM. And he was terribly wrong! Trying to beat an entrenched competitor requires a different governance than leading with disruptive

technology does. This was the beginning of the downfall of the company.

However the mistake that finally destroyed the company was the race for video-recorders where RCA was in competition with several companies, the most prominent being the Japanese company JVC. Ultimately, after a period of erratic changes in direction and blunders, RCA ceased to exist.

But one of the biggest blunders is worth mentioning: that of trying to govern the company by committee in a rapidly moving (for the times) field. This "giving power to committees" was the idea of the son of General Sarnoff who had "inherited" the leadership of the company when his father retired. In contrast, the main competitor (JVC) was directed by the famous Mr. Matsushita who was completely and solely in charge. He embraced the proposed program on video recorders wholeheartedly; and with his total support and clear direction, JVC made rapid progress. At the same time, RCA kept changing its approach in accordance with the whims of the most recent committee. JVC won, mostly by beating RCA on the timing of market introduction. And RCA couldn't recover.

Today we live in a disruptive and exponentially changing world where speed of decision is paramount, a lesson RCA learned the hard way. But also it is important to keep in mind the other "lessons" learned from RCA: the "right" decision and the right governance are also of extreme importance. A final thought? Making the right change is never easy or without risks.

PART IV: THE PROMISE OF THE FUTURE FOR BUSINESS MANAGEMENT

1. *TRACK RECORD OF PREDICTIONS: A CAUTION*

Predictions from 65 Years Ago

Many predictions about the evolution of technology and future inventions have not come to pass. As examples of such wrong predictions, we take a look at an issue of *Popular Mechanics* from 1950. Admittedly this was not the most sophisticated technical publication of the time, but it certainly was a magazine with a large readership, and some of the authors were well-known technical writers.

In the article "Miracles You'll See in the Next Fifty Years" the very reputable Science Editor of the New York Times tried to predict future developments in science and engineering.[16] Some of his predictions included: a) "Houses with 'light metal' walls only four inches thick," (b) "…Wood, brick, and stone will be ruled out (in construction) because they are too expensive and will be replaced by aerated clay cut to size on the spot." c) "When (the housewife) wants to clean the house she simply turns the hose on everything" (Note: no mention of a "househusband), d) To build a helicopter "a punched roll is fed into a machine that virtually gives orders to all other machines in the plant," e) "The house of tomorrow will be built in a few days by pouring concrete into standard forms," f) "Flexible refrigerator bag carries fisherman's catch," g) "De-icing fluid cleans windshield," and (h) "Nose doors 12 Feet high in Globemaster (military plane)."

Of course, there were other predictions that are not mentioned here, but we are focusing on science and on the predictions made by the Science Editor of the New York Times. However it is interesting to note that he paid little attention to electronics, even though technology advances were already occurring in areas such as computers and television.

What Really Happened (Progress in a 60+ year time span)

Yes, some of the predictions listed in the previous section did come to pass: new de-icing fluids, flexible coolers, huge military cargo planes. But the others did not. One can rationalize many of these forecasting "mistakes" by taking into account the thinking of the times. Most predictions were based on a LINEAR extrapolation of the past while the world was starting to change EXPONENTIALLY, making it very hard to predict specific advances.

However, even 60 years ago, one would have expected more attention to be paid to possible breakthroughs related to electronics. Just think about what actually happened. The **transistor**, although invented earlier, was released to the market in the early 1950's. It revolutionized the field of electronics by eliminating the vacuum tube and enabling compact electronic designs.

Then came the era of microelectronics, specifically **integrated circuits** as discussed in Part I. The concept was first demonstrated in a working prototype in late 1958.[17] Then Very Large Scale Integration started being developed in the mid 1970's, resulting in the ability to put hundreds of thousands of transistors on small circuit boards. And today this number has surpassed several billions. These basic inventions allowed the development and mass production of numerous new products and capabilities: from military applications such as guided missiles and drones; to the internet and social media; to a wide range of consumer electronics such as personal computers, cell phones, digital discs, digital cameras and Apple's i-Products; to space (travel to the moon, the Hubble telescope, the Mars rover and more).

Of course there were other breakthrough inventions that were not related to electronics such as polio vaccine, the cloning of animals, and genetically modified foods. But let us return to our focus on electronics. All of the above electronics based list and more happened in a period of 60 years!

What does the failure to predict any of these things mean? It does NOT mean that the Science Editor of the Times did not know his job. It does mean that a person with a moderate to good knowledge of science CAN predict the evolution of existing science and technology, but can NOT predict the advent of breakthrough new inventions and disruptive technologies. Nobody can! There is a clear difference between the "act of creation" of a new idea and the development and commercialization of something that already exists.

But what is impressive in the last 60 years is not so much the failure to predict what happened; rather, it is the enormous amount of change that occurred. It looks like humanity is in a rapid ascent towards more complexity, like a rocket with ever increasing speed. And in this exponentially changing future, what new science breakthroughs might have the most dramatic impacts on business and business management? This is the question we finally address.

2. THE NEXT 50 YEARS: FOUR SCIENCE-BASED AVENUES FOR PROGRESS

Now we make a LEAP forward and try to predict the next big area for inventions or discoveries, similar to integrated circuits, that will propel humanity into the future, changing life and the conduct of business as we know it and creating opportunities for novel businesses and whole new industries. Judging from past attempts, if we made detailed predictions we would almost certainly be proven wrong as the future unfolds. Therefore we will not be very specific.

So how did we make our choices? Think about integrated circuits. It all began with a rather unassuming branch of physics, solid state physics, which at the beginning did not show much promise for useful applications. But when it developed—well, look what happened. Thus we looked for fields like solid state was in its infancy—fields that we felt might provide fertile

grounds for the birth of world changing developments. The only constraints we used in making our choices were the laws of science as we know them today. This differentiates our choices from science fiction. Using this approach, we identified four possibilities which are described below. They all are still very embryonic, and at this time show little promise of practical applications. But give them a few more years and… Keep in mind that technology is now developing exponentially.

New Science from Outer Space: a Really Far Out Idea

Sara Seager believes that we will find signs of life in the Universe around us.[18] A tenured MIT Professor, she has dedicated her life to this pursuit. And she may yet be successful. But she is not alone in her quest. Quoting from a White House report:[19] "…there are a number of projects working toward the goal of understanding if life can or does exist off Earth. Here are a few examples:

- SETI—the Search for Extraterrestrial Intelligence—was originally stood up with help from NASA, but has since been moved to other sources of private funding. SETI's main purpose is to act as a giant ear on behalf of the human race, pointing an array of ground-based telescopes towards space to listen for any signal from another world.
- Kepler is a NASA spacecraft in orbit that's main goal is to search for Earth-like planets. Such a planet would be located in the "Goldilocks" zone of a distant solar system—not too hot and not too cold—and could potentially be habitable by life as we know it…
- The Mars Science Laboratory, Curiosity, is an automobile-sized rover that NASA is launching soon. The rover's onboard laboratory will study rocks, soils, and other geology in an effort to detect the chemical building blocks of life (e.g., forms of carbon) on Mars and will assess what the Martian environment was like in the past to see if it could have harbored life."

If not life, other big surprises may be found in the space around us. After all, the great majority of our surroundings are made up of so-called "dark matter" and "dark energy." Based on standard cosmology models, the total mass–energy of the known universe contains 4.9% ordinary matter, 26.8% dark matter and 68.3% dark energy, according to the Planck Mission Team.[20] So what are these mysterious entities?

Dark matter[21] is a special kind of matter hypothesized in astronomy and cosmology to account for gravitational effects that appear to be the result of invisible mass. Dark matter cannot be seen directly with telescopes, but its existence and properties are inferred from its effects on visible matter, radiation, and the large-scale structure of the universe.

When it comes to **dark energy**, more is unknown than is known. For now it is the most accepted hypothesis to explain the changes in the rate of expansion in the universe that have been verified by multiple observations since the 1990's. Based on these rates of expansion, one can calculate how much dark energy exists. But other than that, it is a mystery.

And of course one cannot ignore **black holes** and whatever surprises they have in store for us. A black hole is a region in space-time where a huge amount of mass is packed into a very small space. The result is an extreme gravitational field that prevents anything, including light, from escaping. Einstein's theory of general relativity predicts that a sufficiently compact mass (such as the core that is left when a massive star dies in a supernova explosion) will deform space-time to form a black hole. As is the

case with dark matter, black holes cannot be directly observed. Their presence is inferred by detecting their effects on other matter nearby.

Dark Matter. Dark Energy. Black Holes. We don't yet understand these mysterious entities, but once we do, or if anything else surprising is discovered in the universe, the impact on our way of life, on business as we know it today, and on our world could be immense.

Sub-Atomic Particles

There are a number of sub-atomic particles that have been discovered—quarks, gluons, leptons, neutrinos, and more. And new discoveries in this field are exciting scientists. Most people have heard of CERN's Large Hadron Collider, the giant particle accelerator that was built in Europe to investigate sub-atomic particles and to allow physicists to test the predictions of different theories of particle physics and high-energy physics. One specific goal was to prove the existence of a new sub-atomic particle referred to as the Higgs Boson or, as some people call it, the "God particle."

To be somewhat more specific, different subatomic particles are responsible for giving matter different properties such as mass. Some particles, like protons and neutrons, have mass. Others, like photons, do not. The Higgs Boson (God particle) is believed to be the sub-atomic particle which gives mass to matter. And in fact, news came not long ago that such a particle had been discovered.

But what are the implications of this discovery and what will come next? How costly would a machine be that allows physicists to take the next step, and what practical applications would come out of these studies? Hopefully not a new weapon, but rather new sources of clean energy, or perhaps something not yet envisioned. Who can say what positive outcomes might be the alternatives if ways could be found to harness the power of the Higgs Boson or other sub-atomic particles.

The Human Brain

Humans have explored much of the earth and some of the depths of the oceans, but there is something even more mysterious and powerful which is much closer to us. It is the human brain, **the most complex living structure that we know of in the universe**! But to date, the human brain has only been explored in a limited fashion. We know about the actions it inspires and many of the individual observable effects that originate from it (e.g., individual personalities, mental diseases, old-age dementia, cowardice, religious beliefs and practices, piety, cruelty, habits, fanaticism). But we are not sure in detail which specific structure of the brain causes which of these effects, and more important, *how*. And we are primitive in our trial-and-error approaches to modifying those traits considered harmful with drugs or surgical interventions.

Think about the contradictions. The brain of Hitler made him kill seven millions of his citizens, mostly because they were Jewish; while the brain of Mother Theresa made her help hundreds of people who were too poor to help themselves, no matter what their race or religion. Genghis Kahn, known as the "scourge of God," is famous for his extreme acts of cruelty during his conquests in western Europe; while Francis of Assisi, practiced charity to all living beings, including (unusual for the times) animals. These are just a few examples of individuals who were led by their brains to live very different lives.

We also know that different people react differently to unusual circumstances, such as to "silence and solitude." This type of environment can spur creativity, but can also lead to insanity. And both can coexist in the same brain as in the case of famous artists like Van Gogh. The human brain also caused migrations of specific populations all across the globe, but not all

populations. Why? And the human brain allows us to transmit ideas and knowledge from one generation to the next. As J. F. Kennedy said, with reference to democracy: "A man may die. Nations rise and fall. But an idea lives on. Ideas have endurance without death."[22]

What would advances and breakthroughs in understanding and controlling the human brain mean for humanity and the business community? The possibilities are vast, and progress is being made. The 2014 Nobel Prize in Physiology or Medicine was awarded to John O'Keefe, May-Britt Moser, and Edvard Moser for discovering the networks of cells that form the brain's navigational system. This fundamental work in neuroscience could have applications in Alzheimer's and other diseases. And this is just the beginning. Through investment in brain research, we may find infinite new ways to harness its power. We do not know yet what they all are, but they will have a major impact on humanity, including human interactions and even business.

Complexity Science

Complexity Science is an embryonic, loosely organized academic field that is developing to study "complex adaptive systems." [23] It encompasses more than one theoretical framework and is highly interdisciplinary, seeking the answers to fundamental questions about the behavior of adaptable systems that consist of changing collections of distributed, interacting components that react to both their environments and to one another.

Typical examples of such complex adaptive systems include: the electric power grid; telecommunications networks; the Internet; the brain and the immune system; the cell and the developing embryo; ecological systems; the global macroeconomic network within a country or group of countries; and human, group-based endeavors and social systems such as political parties, geopolitical organizations, and terrorist networks.

The basic principles of Complexity Science are complicated, so will not be dealt with here. They are explained in detail in several fundamental books on the subject. [24]

As an example of what might be studied by Complexity Science, consider the second principle of thermodynamics, which is accepted by all scientists. This principle states that the entropy of a closed system is always increasing. This means that there is a constant movement towards disorder in all inanimate things in the universe, such as the expansion of a gas freed from a container. Complexity Science, on the other hand, asks: Why then are living organisms evolving towards more and more complex and ordered structures, culminating in the human brain? And it further asks: "Is the cosmic compulsion for disorder (second principle) matched by an equally powerful compulsion for order, structure and organization?" [25] In other words, is there in the universe a force that applies to living organisms and, opposite to the second principle, drives life to ever increasing complexity?

It should be noted that the concept that there is a powerful compulsion for order driving the evolution of living organisms is controversial. Many scientists believe that this evolution can be explained purely on the basis of statistics and survival of the fittest. However proponents of complexity science argue that evolution by itself cannot account for the rapid development and changes of animal and human forms. A disagreement to say the least, with no clear answer yet.

But this is just one example. Today Complexity Science is being propelled forward largely by the "Santa Fe Institute" (SFI).[26] SFI is an independent, nonprofit, theoretical research and education center dedicated to the multidisciplinary study of the fundamental principles of complex adaptive systems. Key

areas of interest are a) physics and computation of complex systems, b) human behavior, institutions, and social systems, and c) living systems: emergence, hierarchy, and dynamics. Specific projects include: Cities, Scaling and Sustainability; Evolution of Complexity on Earth; Hidden Laws in Biological and Social Systems; Emergence of Complex Societies; Neighborhoods, Slums, & Human Development.

So what about the future? How will Complexity Science and understanding the dynamic equilibrium of order-disorder affect life as we know it today? And how might it affect global business interactions and transactions? Again, the only prediction we make is that eventually the impact of this developing science will be great.

CONCLUSIONS

The Problems

The challenges for business management are immense in a world that is increasingly chaotic and changing at an escalating rate. In this article we have identified and explored what we believe are major problems with the way business management is being taught and practiced today. To summarize:

- Typical business management methodologies are already obsolete in a technology-driven world, and exponential change in technology is rapidly increasing the gap.
- Business management is still being practiced as an art in a world dominated by science and technology.
- In the past, intuition, slow decisions, and cautious actions were often ok; but today the rules of the business game are speed and data-driven everything.
- But data, even "big data," isn't the magic bullet. Knowing and understanding what happened in the past (even with detailed and accurate information) can't help forecast (predict) a future ruled by disruptive events and exponential change.
- Committees, no matter how expert their members, are no substitute for decisive leadership and can even be impediments.

Today's Solutions (Now and the Near-Term)

Business management needs to embrace science and technology aggressively and whole heartedly—but wisely.

What can business management do NOW to address the above issues—to shake off the past and start their own revolution? Change is never easy, but as a beginning we highlight actions we have suggested throughout the article to help managers close the gap between their current world of **words** and the new world of **science**.

First, business management needs to embrace science and technology aggressively and whole heartedly—but wisely. Yes, jump on the "big data bandwagon" but don't let it run away with you. Pick your data wisely, understand how it is being analyzed, and always keep in mind its limitations. It can provide much useful information and forecast many trends, but it can NOT predict a future rule by unexpected, disruptive, and exponential changes. Now, continue down the technology path. When making strategic decisions, seek and use the best computer models and data available to explore alternative near-future scenarios and to quantify possible outcomes. Then make choices based on

data, not just intuition. But remember, even the best computer models of today only project probabilities. Nothing is for sure. Judgment and leadership are still essential. However new capabilities are being developed rapidly. So always be on the lookout for more advanced, user-friendly, data-based methodologies that can provide better views of alternative futures.

With respect to "strategic governance," business management needs to structure its organization and business processes to expedite data-based decision-making and actions. This means collecting the right data and using groups of experts to provide important analysis and input but NOT to make decisions. It means clearly defining responsibilities – for data collection and analysis, and for decision-making. And it means reinforcing the role of the CEO as the strategic leader of the organization.

It is always advantageous to be prepared for not only the most likely but also the most unexpected developments of science, including the science of business management.

Directions for Tomorrow (The Future)

The actions highlighted in the last section are a good start at making a major shift in the fabric of business management, but they only address today and the immediate future. What about "tomorrow?" As we have discussed, new and innovative products and processes often "ride on the coat-tails" of unrelated, fast advancing areas of science. Therefore a key question becomes: How can business management keep pace with fast-advancing areas of science and technology and pick the right coat-tails to ride on?

In Part IV we focused on four possible avenues of scientific discovery. Will any of those areas will provide major opportunities for new businesses or the next thrust toward a more rigorous and scientific approach to business management? And what about developments in other areas that we have not addressed, or as yet unforeseen inventions and developments?

No one can accurately predict the future and answer those questions. However if business management can establish an "early warning system" that monitors what is developing in the world of pure science and technology, they will be in a better position to act when something "big" happens. In other words, business management needs to establish an intelligence gathering system focused on science, and advances in Big Data and Business Analytics should be very useful for this kind of endeavor. To say it differently, it is always advantageous to be prepared for not only the most likely but also the most unexpected developments of science, including the science of business management.

One final comment. Although we can't predict the future accurately or specifically, we have confidence in our prediction that businesses in the future will survive and prosper only if management changes and keeps in step with the outside world.

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