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Science-Based Decision-Making

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In today's chaotic world, there is one important business leadership skill that is often ignored: the ability to make effective decisions rapidly. How does a business leader accomplish this? The authors believe such dynamic actions require science-based management methodologies and tools. What is the scientific method all about, and what quantitative methodologies can be useful for decision-making? This article provides a brief introduction for those wishing to embrace "science-based decision-making as a leadership tool.

The ***scientific method*** is a logical, data-based approach to investigating phenomena and developing new knowledge. This method consists of the collection of data through observation and experimentation, followed by the formulation and testing of theories based on that data. If new experiments "validate" the theories (i.e., the theories predict the results of the new experiments), the theories can then be used to predict other future results.

The explosive advances in technology and science of the past 100 years have been made by applying this logical and quantitative method to what was once an empirical world. These large leaps forward were made when science started tackling problems that could not be solved by the deterministic (empirical) approach typical of the 19th century and earlier. Then, toward the end of the 20th century, it was shown that probabilistic theories using advanced computer-based technologies (initially in the field of military strategy) could be applied to problems that were previously thought to be inherently impervious to them, such as business management. Methodologies and tools based on this advance have the potential to change the business landscape irreversibly – but the question is when?

In today's chaotic business environment, those businesses that are technically-oriented already have embraced such scientific methodologies in the operations arena (Research and Development, Engineering, Manufacturing, Finance, and to some extent Marketing). But many business leaders are still using empirical (or even intuitive) approaches for business planning and decision-making aimed at the future. This is inadequate for making the best choices in a rapidly changing and highly competitive global environment. As is stated by an expert:

"Management is out of Date"

> *"Management is out of date. Like the combustion engine, it's a technology that has largely stopped evolving, and that's not good." ("The Future of Management," G. Hamel, Harvard Business School Press, 2007)*

But there is hope. There are management tools and methodologies that are being developed based on the principles of Game Theory and Agent Based Modeling and Simulation (ABMS) that will allow business

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leaders without mathematical training to apply quantitative techniques to business decisions rather than relying on intuition and experience. This will enable risk factors to be analyzed much more thoroughly in shorter time frames, leading to better and quicker decisions. In other words, advances in business management science will help a company to survive and grow when it finds itself in the path of a "Tsunami of Change" or, better yet, to ride that wave to success.

However, it is not the intention of this article to turn business leaders into specialists in using complex mathematical tools. Therefore, only brief overviews of different techniques are provided here. This is meant to increase awareness of their existence and to give enough information to facilitate making a choice as to which available methodologies and tools to use, **if the business situation warrants it**.

Science-based Decision-making

In a disruptive environment such as today's, business survival, turnaround, and growth all depend on making the best decisions and making them quickly. If leaders use a logical process and have rapid access to the right information, they can anticipate the reactions of others and can proactively make better choices. This is what we call **science-based decision-making**, and it increases the chances for business success. In the next three sections we highlight different computer-based methodologies that, to different degrees, inject science into the "art" of decision-making.

Business survival, turnaround, and growth all depend on making the best decisions and making them quickly.

For those not yet convinced of the value of a more scientific approach to leadership, we suggest that you look at one or more of the following references:

1. "Don't Trust Your Gut" by E. Bonabeau, Harvard Business Review, May 2003.
2. "Competing on Analytics: The New Science of Winning" by T. Davenport and J. Harris, Harvard Business School Press, Boston, MA, 2007
3. "Adaptive Business Intelligence" by Z. Michalewicz, M. Schmidt, M. Michalewicz, and C. Chirac, Springer, New York, NY, 2007

These books are not textbooks or technical books, and they represent only a small selection of the writings about "philosophies" on what we are calling science-based decision-making. They all are easy to read and each offers a somewhat different perspective on decision-making in disruptive times. However, they all are proponents of injecting science into the art of decision-making and provide an excellent introduction to the more detailed information in the remainder of this article. Now to the specifics.

Basic Computer Modeling

The various kinds of science-based decision-making methodologies and tools available can be divided into two categories: mostly qualitative and quantitative. In general, qualitative approaches are simpler to understand and use, but they provide only general guidance. However, in a normal business environment, these can be useful. But in the disruptive environment of a post-recession world, more accurate data usually is needed to make the best decisions rapidly; and this requires a more quantitative approach.

The first (and simplest) quantitative approach to decision-making is basic computer modeling. This "spreadsheet" technique is used commonly by businesses today to analyze past financial results and to construct a future financial forecast based on an extrapolation of the past results. Business Leaders then can use this information as the basis for their strategic

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and tactical decisions. This conventional approach is based on simple mathematical formulas and works fairly well in a relatively stable environment (calm economy, a steady and growing business, predictable competitors, no unexpected disruptions). In these circumstances, such basic tools may be adequate, and need no further description.

However, when disruptive changes occur, extrapolations of the future based on the past are no longer relevant. In other words, the past is no predictor of the future. The "game" has changed and you don't know the "rules". New methodologies and tools (such as described in the next two sections) are needed to predict quickly and more accurately possible future results.

Game Theory

Game Theory is an example of one powerful science-based approach that can more accurately evaluate alternative "futures". What is Game Theory? 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.

Game Theory attempts to mathematically model behavior and predict results in competitive 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 the players.

The basic principles of Game Theory can be applied qualitatively to provide general guidance, but a full quantitative model may be needed to predict outcomes in the complex and dynamic economic environment of the post-recession world. The general characteristics of these two approaches are described next.

First, consider what we call "**Qualitative Game Theory**". This is a logical process that uses the basic concepts of Game Theory (but not the complex mathematics) to create simple models of competitive business situations. The model framework is developed by establishing: the players, the goals, the possible actions (assumed to be rational), and the constraints (including timing). Sometimes just having this information is valuable. The game is "played" by answering logically "what if and then what" questions for all possible actions by the players. Visualization of the game is helpful and is often accomplished by using a matrix approach or a "decision tree" diagram (for examples, see the second book referenced below). Usually this type of "game" will clearly identify some options that are undesirable and others that deserve further consideration. Therefore, although the guidance is general, qualitative Game Theory can be a useful decision-making methodology when timing is critical and mathematical experts unavailable.

On the other hand, **Quantitative Game Theory** 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

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complex, it can be worthwhile for a large company or a complicated business situation. It is particularly useful for exploring alternatives when there are multiple players, conflicting goals, and many action options. However, be cautious. The more complex your 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, quantitative Game Theory can be a powerful tool, but 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 references below provide additional information about both qualitative and quantitative Game Theory.

1. "Co-opetition: A revolutionary mindset that combines competition and cooperation. The Game Theory Strategy that's changing the game of business" by A. Brandenburger and B. Nalebuff, Doubleday, New York, NY, 1996". A landmark book which uses the principles of Game Theory (qualitative) for developing business strategies. It teaches the "game" of business and how to change that game.
2. "Game Theory at Work: How to use Game Theory to outthink and outmaneuver your competition" by J.D. Miller, McGraw-Hill, New York, NY, 2003. A somewhat more technical description of the basics of Game Theory for the non-expert. Provides easy-to-understand examples of different business "games".
3. "Games, Strategies, & Managers: How Managers can use Game Theory to make better business decisions" by J. McMillan, Oxford University Press, New York, NY, 1992. A very readable, nontechnical book that applies the general principles and logic of Game Theory to basic business decision-making. A good introduction to the ideas.
4. "Games Businesses Play: Cases and Models" by P. Ghemawat, the MIT Press, Cambridge, MA, 1998. Uses detailed case studies (examples) of actual business interactions to explore the uses and limits of quantitative Game Theory as a strategic decision-making tool. More analytical and less descriptive than the preceding references.
5. "Game Theory, a Critical Introduction" by S.P. Hargreaves-Heap and Y. Varoufakis, Routledge, New York, NY, 1995. More of an academic introduction, but relatively nontechnical. Good descriptions of the elements of Game Theory and the different types of games.

You can also find additional articles and references through online research. One of the sites that you may find useful is: **http://www.gametheory.net/links/consulting.html**. This Web site lists a number of consulting firms specialize in Game Theory. Note: EFMA does NOT have knowledge of any of these firms, and hence this reference should in no way be considered a recommendation.

Agent-Based Modeling

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 somewhat simpler science-based tool.

ABMS is a computer-enabled methodology that describes (and predicts) the evolution of dynamic "systems"

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

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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 AMBS 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.

The following references all provide good, but different, introductions to ABMS.

1. "The Complexity of Cooperation: Agent-Based Models of Competition and Collaboration" by R. Axelrod, Princeton University Press, Princeton, NJ, 1997
2. "Agent-Based Models" by N. Gilbert, Sage Publications, Thousand Oaks, CA, 2008
3. "Managing Business Complexity: Discovering Strategic Solutions with Agent-Based Modeling and Simulation" by M. North and C. Macal, Oxford University Press, New York, NY, 2007

The first provides a historical perspective of ABMS, and the second contains examples of different applications of ABMS in the social sciences. The third is more of a "complete" business-oriented resource text that describes ABMS and then teaches how to build simulations and apply them to business decision-making. Therefore, although still understandable to the non expert, it is the most detailed and technical of the three books.

Additionally, the following Internet articles (full text available online, no charge) provide good general overviews of ABMS and/or actual examples of ABMS applied to business situations.

1. "Agent-based modeling: Methods and techniques for simulating human systems" by E. Bonabeau: **http://www.pnas.org/content/99/suppl.3/7280.full**
2. "Predicting the Unpredictable – Can You Predict the Unpredictable?" by E. Bonabeau: **http://hbswk.hbs.edu/archive/2934.html**
3. "Agent-based Modeling: A valuable new weapon for Chief Marketing Officer in the fight of their lives" from the EMM Group: **http://www.decisionpower.com/news_and_events/pdf/AgentBasedModeling.pdf**
4. "An Agent-Based Model of the Airline Industry" by W. Niedringhaus: **http://www.caasd.org/library/papers/ACSEM.pdf**
5. "The Aero-Engine Value Chain Under Future Business Environments: Using Agent-Based Simulation to Understand Dynamic Behavior" by D. Buxton, R. Farr,

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and B. MacCarthy:
http://www.xjtek.com/file/10/

6. "Agent-based modeling for competing firms: from balanced-scorecards to multiobjective strategies" by T. Terano and K. Naitoh:
http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=1265251

A topic we have not dealt with is so-called "Participatory ABMS". This is a technique where human Agents are included in ABMS. The following reference describes this in more detail, including potential advantages.

"Agent-Based Participatory Simulations: Merging Multi-Agent Systems and Role-Playing Games" by P. Guyot and S. Honiden: (**http://jasss.soc.surrey.ac.uk/9/4/8.html)**

We hope that this very brief introduction to "science-based decision-making" has convinced you of the value of this leadership approach in today's chaotic business environment. Although there is no guarantee of "winning" in turbulent times, using a more quantitative and data-based methodology for business management will optimize your chances of successfully "riding" the Tsunami of change.

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