Quantitative Portfolio Management for Initiatives

A methodology for managing initiatives in an organization based on

Financial Portfolio Management Theory

And

Deming's Theory of Knowledge

Introduction & Background

Part - 1

By

Gustavo Zambrana

1.0 Overview

What is Quantitative Portfolio Management of Initiatives (QPMI)? What is it about? What are its theoretical and scientific foundations? Why should an organization care? What can it do for me? This monograph answers all of these questions. There are many sources of information on the Web, in fact, thousands regarding Project Portfolio Management, yet the clear majority are focus on managing a list of projects from an execution perspective in a qualitative way; some exceptions are the articles and books listed in the reference section of this document.

There are several books about project portfolio management; their focus is targeted to some aspects of project portfolio management and project centric. There are not standards or consensus; yet one only needs to refer to Financial Portfolio Management to draw an initial understanding of what QPMI might be and involves. The PMBOK documentation for IT Portfolio Management is abstract, consisting primarily of generic process recommendations and integration points with Program and Project Management standards under the PMBOK guidelines. The PMI Institute does not address any of the following areas in portfolio management: Other Program Management methodologies, Decision Making for initiatives in a Portfolio, Value Creation, Value Delivery, and Uncertainty. This latter topic is discussed at a very high level in section 8.1.2.3 of the official PMI documentation for Portfolio Management (Reference [65]).

The focus of this disquisition is dispensing details in defining all aspects of portfolio management for initiatives, providing the peruser a comprehensive introduction to the domain and the reason for its existence and challenges. The following topics will be discussed:

- Historical background.
- The underlying concepts and principles.
- The frame of the problem to solve.
- Define what encompasses the domain of portfolio management of initiatives.
- The relationship of Portfolio Management to other disciples in an organization.
- The questions a portfolio management of initiatives methodology aims to address.

A formal treatise solving the framed QPMI exposed in this monograph will be the subject of future work, covering an axiomatic general theory and various methods and examples to address each of the objectives of QPMI laid out in this discourse.

The reader can choose to read the second part of this monograph, section 3. Alternatively, It is recommended to start with the review of the historical foundations, enabling technologies, and theories under which QPMI is based on. Particularly, if the reader is not familiar with the concepts of Statistical Process Control, Stochastic Processes, Bayesian Methods, Cognitive and Heuristic Theory, Financial Portfolio Management, Decision Making Theory, Entropy, and the relationships among Uncertainty, Variation, and Risk.

The author's understanding and framing of the problem (and solution) leverages the theories, methodologies, and ideas of giants, notably: W. Edwards Deming, Eliyahu Goldratt, R.A. Howard, Edwards Ward, Harry Markowitz, D. Kahneman, A. Tversky, Pierre Simon Laplace, Thomas Bayes, Walter A. Shewhart, Ralph Keeney, Howard Raiffa, Claude E. Shannon, John M Keynes, and E.T Jaynes. In the spirit of Agile, I expect that through continuous learning, discoveries will change and improve how the quantitative answers are obtained but no the overall objective of QPMI and the questions that must be answered to manage a portfolio of initiatives in a systematic and analytical manner; the path of progress should reflect the evolving refinement and enhancements to Modern Portfolio Theory in the finance world since 1959. One of the primary goals underlying the overall approach is self-reflection and continuous improvement, and this key insight; it is directly applicable to the methodology introduced in this document.

Gustavo Zambrana

2.0 Background

2.1 What is Quantitative Portfolio Management of Initiatives (QPMI) and Why an Organization Should Care?

A Portfolio Management System of Initiatives is a collection of strategically aligned group of objectives, governing processes, and methodologies selected to maximize the odds for generating maximum value in the future subject to an organization's risk tolerance and constraints (cost, resources, etc.).

QPMI's goal is to determine the optimum portfolio of initiatives that maximizes the creation of value for an acceptable level of risk, what an organization "values," and the rate at which this value is created. There may be multiple kinds of "values" depending on the company and the intent of the portfolio. QPMI can be thought of as a complementary process methodology to Agile enable enterprises. However, QPMI does not require an organization to be Agile to rip the benefits from its utilization.

The purpose of an Agile Enterprise is to accelerate the creation of "Value" and get fast or immediate feedback from customers and users to validate the hypothesis of ideas developed (e.g. requirements, features, user-stories); did the functionality provided the expected benefits? The objective of QPMI is to enable the second part of an enterprise optimization, deciding which initiatives to develop and fund based on the limited resources of an organization, and secondly when to do them. The shared goal with Agile is maximizing "Value." Agile methodologies optimize the value creation and delivery at the micro level, project-product instance, while QPMI optimizes across the enterprise. Focus is on the selection of initiatives that have the greatest likelihood to generate maximum "Value" within the accepted constraints and risk tolerance of an organization.

Do not confuse QPMI with the management of projects in a PMO or a Program Management environment. The latter objective is delivering projects subject to the triple constraint: scope, time and cost and provide guidelines and processes to follow up on the execution of these projects. QPMI is agnostic to the actual Project Management methodology, yet it does require that all methodologies become aware and knowledgeable of uncertainty, and more importantly that it is incorporated in their planning.

"Either you learn to manage Uncertainty, or it will manage you. – Unknown"

2.1.1 Where does QPMI fit in the Organization Strategy and Execution?

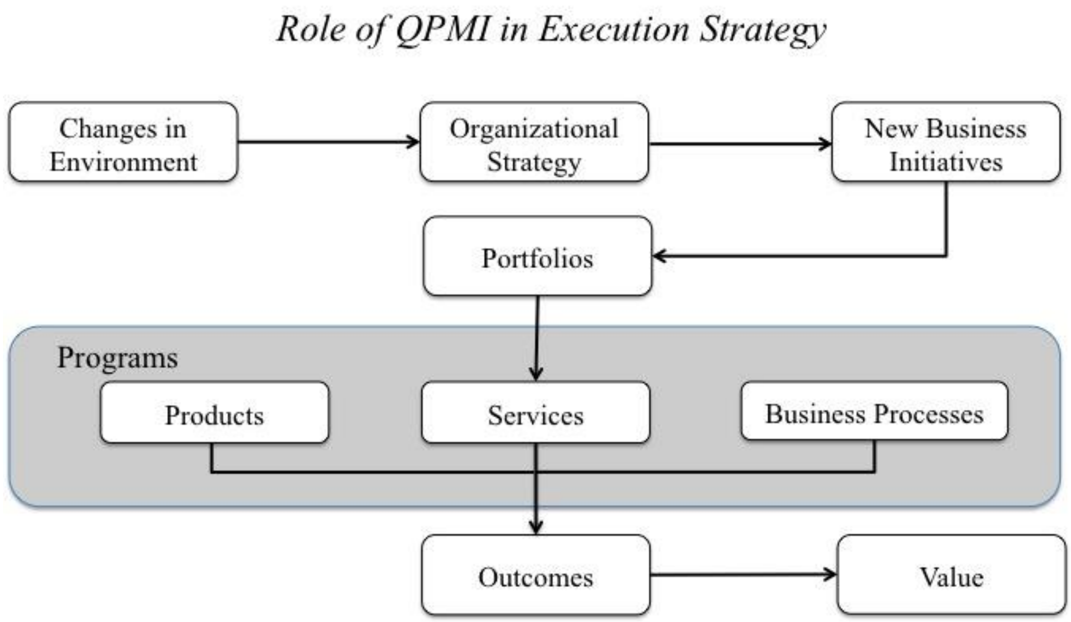

Figure 2.1, Role of QPMI in Execution Strategy

2.2 Historical Roots

2.2.1 Theoretical Foundations

Project Portfolio Management Foundation is eclectically rooted on several theories. The aim of QPMI is to provide a systematic and analytical methodology for organizations to select and execute a set of initiatives; the criteria are to maximize value subject to an organization's constraints (resources, capital, etc.), and strategic goals, given the company's risk tolerance. QPMI is very similar to Modern Portfolio Theory (MPT) for financial assets; however, unlike its financial sibling, QPMI also has additional requirements. Most of these requirements were not possible to address over the past 50 years, until breakthroughs in Economics, Psychology, Mathematics (algorithms), Process, Decision Science, and Data Analysis occurred. Based on the goals of an organization, the complexity of a given initiative in the portfolio, the configuration and customization of QPMI will leverage different foundations and enabling methodologies discussed in the following sections.

2.2.2 Modern Portfolio Theory

Nobel Prize winner Harry Markowitz pioneer the revolution in financial investing known as Modern Portfolio Theory (MPT) in 1952, with his seminal paper, *Portfolio Selection*. Markowitz proved that investors can attain significantly higher return at lower risk if, instead of picking assets based on their individual maximum, the selections are based on calculating the overall impact on the risk and return generated by the portfolio. Markowitz realized and proved that certain combinations of assets, portfolios, are efficient; these portfolios lie on the "Efficient Frontier" as he educed, efficient since they create the greatest possible expected value for the least risk; other portfolios exist that create the same expected value but for greater risk. Only one corresponds to the highest expected value for a given risk level. It was Markowitz conclusive findings, as a result of his insight and profound work, that Inefficient Portfolios should be avoided. Furthermore, he concluded, the choice of which of the efficient portfolios is best depends on the investor's risk tolerance; that is, willingness to accept a risk level. This latter concept Markowitz directly tight to Economy Utility and deduced the relationship between the Efficient Frontier and the utility function for a given individual or organization.

What enabled Markowitz to make this breakthrough was a clear understanding of the investor's true goal; namely, to obtain the portfolio of investments that returns the greatest possible value, considering willingness to accept risk. This perspective led Markowitz to a different and much better strategy for selecting investments. Although Markowitz may not have anticipated it at the time, the same reasoning applies to organizations investing in initiatives. An organization's goal is to choose the portfolio that creates the greatest possible (risk-adjusted) value for the company. Likewise, this revised perspective leads to a much-improved initiative-selection strategy.

Modern Portfolio Theory (MPT) for financial assets is an ever-evolving field, as recently demonstrated by Rebonato's MPT's work (Reference [83]) and endorsed by Dr. Markowitz himself. The primary focus of Rebonato's work and others is a more inclusive and comprehensive appraisal of future uncertainties in the assets of a portfolio. This latter aspect of MPT is also encountered in the management of initiatives; both types of portfolio must deal head-on with risks caused as a result of all the different types of uncertainties (section 2.3). It is not sufficient to formulate an evaluation of a financial portfolio solely on historical data, understanding the uncertainties in the future and how they might impact the value assets it is paramount to derive the most realistic assessment possible for what may transpire in the portfolio. Neglecting to consider risks from all types of uncertainties, do not make the risks less real and go away; it just gives a false sense of security and understanding of what the future reality might be. Including analysis of all uncertainties does not mean, the portfolio will be impervious to surprises, this will never be possible, due to black-swan events, but as discussed later, the attention is a shift in analysis, from what to invest on to can the organization survive the worst-case scenarios and black-swan events? Is there anything that can be done to mitigate them? The reader is reminded of the 1998 and 2008 market collapses; they were forecasted with less than 1 in one Billion odds of occurring.

Historically, MPT has been utilized with historical data to predict the future to access the volatility of assets and to a lesser degree their expected value. However, there is nothing in MPT that recommends or prescribes relying exclusively on past data to derive the variance and expected value of assets. The last 20 years has clearly demonstrated the faultiness of focusing solely on historical data; it led to multiple meltdowns in Wall Street in the nineties, the Russian Rubble debacle, Emerging Bond Markets collapse, the Real Estate and Investment market collapse from 2008 (References [82], [85]). The failure was not with MPT, but with the systematic failure to neglect risks from all type of uncertainties. Most of the analyst's findings concluded these events were less likely to happen than 1 in 1 Billion years, others even less (Reference [98]). These flaws in the quantification of risk in the finance world were mainly due to two factors; first, assuming that the events from the past represent the likelihood of the future (draws from the same experiment under the exact same conditions in probability theory). Second, underestimating and disregarding consideration of all the types of future uncertainty. Economists John Keynes and Frank Knight warned about the latter reasons about a century ago, in 1921, their concerns fell on deaf ears regretfully.

The core problem of MPT and QPMI boils down to decision-making under uncertainty, understanding and quantifying the uncertainty in the future, which can then be used to gauge the potential losses and gains of value for a given risk level. In the finance world, the uncertainty could be due to a variety of reasons, including wars, monetary devaluations in foreign countries, economic growth, trade agreements, government policies, and interest rate changes. The uncertainty in QPMI's domain is associated with the value expected to be created by initiatives, the prospective value of an initiative is subject to market and environmental forces, technology, meeting customer expectations, competition, and timing to list a few.

2.2.3 Historical Challenges Implementing a Portfolio of Initiatives

Despite the analogy between financial and initiative investing, there are some critical differences. Organizations conduct initiatives because they believe they will produce consequences that are good for the business.

Therefore, the value of a portfolio of initiatives is determined by the worth to the company; the benefits gain after delivering those initiatives. The business consequences of delivering initiatives may include improved tangible financial benefits (e.g., cost savings, increases in revenue), but there are other types of benefits that cannot so readily be expressed in dollar terms. For example, initiatives may be conducted for the purpose of improving worker safety, customer service, productivity, compliance, organizational capability, and relationships with business partners.

Another key difference relates to uncertainty. The returns from financial investments and IT initiatives are both uncertain. However, unlike financial assets, data on past performance is not usually available to help quantify uncertainties for candidate portfolio initiatives. Corporate initiatives are in most cases distinctive, "Creative Knowledge Work" projects. Knowledge work is empirical and no deterministic; this leads to difficulties measuring an initiative's plausible value, challenges for directly applying standard Financial Portfolio Theory to Portfolios of Initiatives without extensions and modifications to MPT.

2.2.4 Breakthroughs

Since Markowitz's time, additional advancements and breakthroughs necessary for optimizing Portfolios of Initiatives have been achieved. These advances include:

1. *Influence diagrams* to identify factors affecting the achievement of objectives and probabilistic impact.
2. *Consequence modeling* for estimating or simulating the impact of decisions on business performance.
3. *Probability encoding* techniques for eliciting probabilities based on subjective judgments.
4. *Stochastic Process Models* to simulate potential outcomes of any decision, program, and portfolio leveraging Monte Carlo, Bayes Networks, Monte Carlo Markov Chains algorithms, etc.
5. *Decision Science Theory* for making optimal decisions across alternatives in a rational, systematic, and quantitative manner.
6. *Bayesian Networks and Probabilistic Programming* for making decisions and quantifying uncertainty for initiatives.
7. *Deming's Theory of Profound Knowledge* and *Understanding of Variation*.
8. *Walter Shewhart's Theory of Statistical Process Control.*
9. *Multi-Criteria-Decision-Analysis (MCDA) and various methodologies to support decision-making across all types of environments and decision types. The most relevant ones are Multi-Attribute Utility Analysis (MAUT), Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), PROMETHEE (Outranking method, among others). Some new emerging MCDA methods include ProMAA and Fuzzy MAUT; both methods are enhancements to MAUT providing increase probabilistic modeling or Fuzzy Logic techniques.*
10. Advances in the understanding of human's judgment and decision-making process under uncertainty, based on scientific advances in *Cognitive Psychology* and *Behavioral Economics*. Research and work by Nobel Prize winners Daniel Kahneman and Amos Tversky on Prospect Theory.
11. Nonlinear Systems – Chaos and Fractal Theory. These subjects provide explanations of many of the physical and economic phenomena in the world, the outlier events.
12. Entropy and Uncertainty. E.T. James generalization of Shannon's Entropy as a measure of uncertainty.

At the time of Markowitz's discovery, the relevant methodologies, algorithms, computational power, still were not ready and it was necessary to wait for improvements in computer technology and software engineering to become fully operational. Bayesian methods were still obscure and difficult to employ; mainly used by a small niche of users (due to historical rivalry with Frequentist Statistics). Cognitive Psychology and Behavior Economics was in its infancy, and the work of Kahneman and Tversky had not yet been published. Deming's theory started to be utilized in Japan and did not become widely known and used in North America until the 80s; Decision Science was just emerging in the 60s. However, only recently have companies have attempted to create commercial products for Project Portfolio Management, typically under the acronym PPM (Project Portfolio Management) denoting their focus on managing a set of Projects.

2.3 Uncertainty, Variation, and Risk

These terms mean different things to different domains and individuals. Yet, it is of most importance to clarify their meaning in portfolio management and their relationship. Humans have encountered events that could not be explained ever since the beginning of our existence, using the terms “chance”, “randomness”, “mystical” to name a few for their description or likelihood of occurrence. The potential consequences of such events occurring labeled as risk, bad-luck, destiny, among other adjectives depending on the individual's background and personal belief system. Variation, another popular term in multiple industries and cultures, can be interpreted to mean the degree of change, more often than not, it is attributed to humans’ lack of effort or attention to detail for a task or job, as Deming’s insight illuminated.

Uncertainty, risk, and variation are critical concepts in the Financial and Project Portfolio Management world. It is necessary to establish their meaning and context as applied to the methodology discussed here. The following sections provide a summary of the meaning of these critical concepts, their relationship, and the definition of their meaning in order to apply them to various aspects of the problem at hand. The concepts and definitions leveraged in QPMI are based on the work of Terje Aven (References [86-88]), Nassim Taleb (References [29, 85]), Seismic Hazard Engineering, Deming [References [36,37], Shewhart (Reference 40), Wheeler (References [46-49]), and Financial Risk Management industry (Reference [84]) among others.

2.3.1 What is Uncertainty?

“The Risk of losing any sum is the reverse of Expectation; and the true measure of it is, the product of the sum adventured multiply by the Probability of the Loss . – De Moivre 1711”

“There are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we know we don’t know. But there are also unknown unkowns. There are things we don’t know we don’t know. – Rumsfeld 2002”

The famous quotes above denote the historical preoccupation with risk and uncertainty. An eighteenth-century mathematician and a recent political figure, the Secretary of Defense for the United States. Both figures arrived at different definitions of uncertainty and the consequences it forces upon us, humans, to make decisions. The statements illustrate clearly that the simplicity and mathematical foundation of risk per De Moivre are subject to many assumptions, the context and meaning of risk can be as simple as De Moivre stated, as long as one understands the assumptions and limitations to which it applies.

The concept of risk it is meant to enable us to make decisions under uncertainty, the future cannot be predicted with certainty. The most common example is the coin-toss experiment, what would you bet on a coin flip, based on what odds? Most people without any experience in Probability Theory would immediately assume a fifty-fifty likelihood of winning or losing, and depending on the odds offered for the bet; they might accept it or no. This simplistic example demonstrates the limitation of our thinking regarding chance or probability (a concept defined later), as we are assuming that the coin is a fair coin, this information is not stated, and most people assume it. How do we know the coin is fair? A Martian visiting from another world might not be predisposed to make the fifty-fifty assumption. In general, when making decisions under uncertainty we are forced to make assumptions regarding what we know, what we don’t know, and what we have no way of knowing.

De Moivre’s definition regarding risk is an approximation, as we can never be certain regarding our understanding of the uncertainty in a decision. Having said that, it is important to realize that the degree of the approximation varies depending on the type of uncertainty upon which we need to decide on. The other factor to consider is the consequences of the decision if the uncertainty occurs. Every time we drive, flight, we are making a subconscious decision to pursue the action, we accept the odds of an accident as very low, more than extremely unlikely to occur, otherwise we would not put our life at risk of death. Yet, what if we have been warmed by some, not all, meteorologists of an incoming solar storm with a one in ten-thousand chance of occurring during the next month, and the consequence of this event could potentially crash an airplane in mid-flight with 1 in 1000 odds. Would one re-considered flying over the next month or two? The same scenario can be extended to the threat of terrorism, which is now considered by most individuals as non-negligible, but this assumption was not considered 30 or 40 years ago. Decisions are always subject to uncertainty, for which we may or may never know all the potential events that may affect the odds of it occurring, the famous Black Swan effect as exposed and documented by Nicholas Taleb.

What are we to do? We should accept and understand the limit of our knowledge regarding decisions we are to make, and the extent of the negative or positive consequences associated with the uncertainty in a decision. Behavior Economics is a field that has entered and altered our understanding of how we humans actually make decisions, which it is not strictly rational, but driven by our cognitive biases and the framing of the decision at hand. This is the academic world of Prospective Theory; this topic is discussed later, but the important point to be aware of, it is how it influences how we humans react to uncertainty, and how we make decisions subject to it. Prospect Theory is not an axiomatic discipline as Neoclassical Economics, it is empirically deduced, and therefore real, and its effects on the decision-making process ought to be no ignored (see Section 2.4.5).

The latter discussion on uncertainty leads us to the point that Secretary Rumsfeld was making, that uncertainty is a continuum. It ranges from that which we are certain of at one end through that which we are completely ignorant of, at the other end. For the purpose of understanding and providing meaning to the uncertainty spectrum, the approach preferred in this monograph is combining the Seismic Hazard Engineering domain, Black Swan events (also known as a type of “Ontology Uncertainty), and separate the categorization of the uncertainty spectrum into three broad categories: Aleatory, Epistemic and Ontological uncertainties. Each category has specific properties, the most important of which is the characterization of if and how to quantify the uncertainty, i.e. translating the uncertainty to risk. Depending on the type of uncertainty this may or may not be possible quantitatively. The categorization also provides the benefit of clarifying the mathematical mechanism to employ depending on the uncertainty type, and the limitations of our knowledge if it is an Ontological Uncertainty.

2.3.1.1 Uncertainty and Ergodicity

This topic of discussion is philosophical and technical, but relevant to understand the limitations we humans face in making predictions. Discussion regarding the relation between uncertainty and ergodicity can be traced back to the 1920s, in the work of two of the most famous economists of the 20th century, John Keynes, and Frank Knight, and their corresponding books, “*A Treatise on Probability”* and “*Risk, Uncertainty, and Profit.”* Why should we care about ergodicity? We care because we need to make decisions subject to uncertainty. In their domain, the uncertainty is around the economic-financial world, which it is a similar challenged facing QPMI, what initiatives to choose based on internal and external factors, market and environment forces, technical complexity, human knowledge, cost, regulatory, and legal uncertainty among others? In essence, from the macro level, initiatives are subject to uncertainty because it is not known the actual value they can generate if any at all, the cost, and the possibility an initiative will not complete for any number of reasons.

Ergodic systems might seem like an obscure mathematical concept, in my opinion, it is the name that makes it confusing. Mathematicians have a fascination naming abstract concepts with obscure Greek or Latin words; the term ergodic is derived from two Greek words, ergon for work and odos for path or way. This mathematical concept states that dynamical systems, however complex they may appear, their behavior and work over time is the same in average, that is, in average, they have a probabilistic behavior which can be deduced. Therefore, the ability to predict these dynamic systems has to do with our limited knowledge and understanding of the system. In theory, we mortals just need more time and observations of how the system behaves to be able to predict their future behavior. The philosophical side of the argument is that in theory, dynamic systems are ergodic, however rare some events of that system might occur, their behavior on average is predictable. The underlying conjecture is that if we only have more knowledge we could prognosticate them, and it is our limitation, our models, our lack of knowledge, and data points that are the problem, this type of uncertainty has been categorized as Epistemic. On the other side of the argument, the opinion is that many systems are non-ergodic, that is, it is impossible to predict them, this type of uncertainty is labeled Ontological, and it is commonly associated with Black-Swan events. Now, this is where things get interested, Nassim Taleb, who coined and explained the Black-Swan concept, stated in his original book that the nature of the uncertainty regarding Black-Swan events is ergodic, and in his latest revision of his famous book from 2010 (The Black Swan), he acknowledges that there is the nonergodic possibility, but in practicality, he concluded, it does not matter, as we are not able to calculate probabilities in either case.

John Keynes and Frank Knight provided additional perspective on this topic. Keynes opinion is that economic and financial markets are non-ergodic systems, the historical data from the past, it is of little relevance, and the probabilities of the past do not rule the future, the system is ever evolving, not a replica of the past. Knight, on the other hand, believes that economic and financial markets are ergodic systems, because the market should behave based on rational principles of economics, and therefore all economic events, in theory, are part of an ergodic system that is homogeneous and should be predictable. Thus, there is a stochastic model that describes on average, this future reality. An insightful discussion on this topic by Paul Davidson, founder, and editor of the Journal of Post Keynesian Economics discusses the argument from both sides (see Reference [89]). My opinion is that economic and business decisions are non-ergodic as well as ergodic, and it depends on the particular decision, initiative. Why does it matter which type it is? Because if the uncertainty is ergodic, we can try to apply Bayesian Analysis for inference and therefore calculate the quantitative risk for these events. If it is nonergodic, there are not experts, hypothesis or data that can help; the subject is unknowledgeable. We just don't know what we don't know (the meaning behind Rumsfeld quote above), and our focus ought to be on the impact of the black-swan events to make sure we can survive them. The choice to conduct the impact analysis for potential black-swan events depends on the nature of the decision under uncertainty to the decision maker. Some might argue, it is unknowledgeable, why bothered? Because it is the pro-active approach that will force us to consider possibilities, which might lead us to act and prepare for them, easily discounting this analysis, it is at our own peril.

2.3.1.2 Uncertainty Categories

2.3.1.2.1 Aleatory Uncertainty

The word "Alea" is Latin for dice. This type of uncertainty represents the inherent randomness in processes, actions, events in nature. This uncertainty is associated with the inherent variability of basic information, which is part of the real world, it is within our ability to observe and described. The fundamental concept of Aleatory Uncertainty is that is "Knowable," but not irreducible to zero. The more data we collect for these type of uncertain events, the better our understanding of them and our predictions, but it will never be zero.

A way to visualized Aleatory Uncertainty is as that which is located in the spectrum of things we know, we understand, but only up to a point, no matter how much data we collect to study the uncertainty at hand. For example, throwing a die, tossing a coin, playing a game of cards are all samples of games that we understand, but no matter what, our ability to predict the future is always within bounds, and in this example, we expressed our knowledge as probability distributions and corresponding moments. Another form for this type of uncertainty is process related; all processes are subject to uncertainty, human or mechanical based. In the case of human processes, there is an inherent variability as we humans can break, get sick, the complexity of the task, our disposition to misunderstand or miscommunicate, etc. And even in the technical-mechanical end, parts become defective; instruments are only accurate within a given tolerance, the quality of materials can vary, etc. Yet, we can understand these processes and infer their performance and predict their behavior within limits, as long as they are statistically stable. This is the subject of Process Variation; it is discussed in section 2.4.4.1. Suffice to say for now, that no process is deterministic; all processes are subject to variation, which is associated with Aleatory Uncertainty.

Summarizing, the characteristics of Aleatory Uncertainty are:

- Natural randomness in the world in things we know. That is processes, measurements, and actions with known outcomes but subject to random variability (games of chance).
- The more data we have regarding the event under this uncertainty, the more precise our understanding of its underlying behavior, as represented by Probability Theory.
- If the event or action is associated with parameters and these parameters can take a set of concrete values, which we cannot pre-determine.
- Probability Theory (Frequentist or Bayesian) can be utilized to forecast odds.
- All human, technical and mechanical processes are subject to Aleatory Uncertainty when they are statistically stable, if they are not, they could be subject to Epistemic or Ontological uncertainties, and their behavior unpredictable, until these types of events affecting the processes are addressed.

2.3.1.2.2 Epistemic Uncertainty

The word "Episteme" is Greek for Knowledge. This type of uncertainty represents the scientific uncertainty in a model of a phenomenon. Multiple models characterize it. In theory, it is possible that this kind of uncertainty can be reduced or eliminated, but it depends on what can be learned in the future. This type of uncertainty can be best understood as our limited understanding of the real world; we have imperfect knowledge, which could be reduced by better prediction models and improved experiments, in theory, but we can never be sure.

Epistemic uncertainty represents a general and potentially solvable lack of knowledge. This uncertainty is something we comprehend, and we understand; it is our lack of knowledge that limits us in its characterization. Our knowledge on this type of uncertainty, it is subject to assumptions, and even so our predictability could increase from increase knowledge, it is limited to the assumptions stated. Should those assumptions no longer apply, then our understanding of the phenomenon will not be as we thought of. It is this modeling, these assumptions about applying our knowledge that is at the center of this type of uncertainty. Typical scenarios under Epistemic Uncertainty are Economical and Environmental models of the world. Many assumptions characterize economic models; the fact that they might produce predictable results within a specific time period (the shorter, the more accurate) does not mean that we understand the modeled phenomena. The casual effect relationship can be nonlinear and affected by future conditions. For example, at the time of this writing, April 2016, there are multiple concerns regarding the world economy. What potential impacts and likelihood will the Chinese Economy, ISIS, and the future US election have in the US and global economy? How will these events manifest themselves and at what rate? Whatever models are build, will usually be based on historical data, and that can give us an idea of the dispersion, variance on the uncertainty, but do we really know? The world is now more than ever economically interlock; can we ever predict? This type of modeling can enter the world of Black-Swans (Ontological Uncertainty) based on the opinions of many, as clearly documented by Nassim Taleb.

In summary, Epistemic Uncertainty becomes even more displayed when we evaluate the likelihood of a rare event for which minimum or no empirical data exists. Events for which we have to rely more heavily on subjective expert estimation, which has cognitive biases associated with it per the novel winning work of D. Kahneman and A. Tversky (References [1,2]). Additionally, subjective knowledge is subject to Bayesian Analysis, and the methodology and process to validate this collected expert knowledge must follow specific rules to be valid; all probabilistic estimates are conditional, it is the understanding of those conditions and how they are evaluated and interpreted that becomes critical along with the cognitive biases. The beauty of this method, it is that forces us to accept our limitation of knowledge and no full ourselves with more accurate knowledge that we should consider in our analysis, ultimately in our decision-making under uncertainty. Neglecting such limitations and biases can lead in turn to erroneous results as underestimating the length and thickness of the tails in derived probabilistic distributions, resulting in the likelihood of extreme events significantly underestimated, or worst discounted entirely. In such circumstances considering the future from a possibilist rather than probabilistic standpoint may turn out to be the wiser course, and focus on the potential outcomes and mitigating process to limit their potential impact, this is the focus of Event Tree Analysis (ETA) in the engineering and safety disciplines.

Summarizing, the characteristics of Epistemic Uncertainty are:

- Due to lack of knowledge.
- Scientific uncertainty in the model of a process or phenomena.
- If the uncertainty is associated with one or more parameters, but we don't know which or their frequency.
- Additional knowledge can increase our understanding and predictability of the phenomena. In theory, the degree to which this is a true fact depends on what it is.
- Bayesian Analysis is the preferable mathematical approach to estimate probabilities for epistemic uncertainty due to the subjective nature and lack of repeatability and data to leverage the frequentist probabilistic approach.

2.3.1.2.3 Ontological Uncertainty

Ontological uncertainty is most often associated with Black-Swan events, but these events are just one of the different event types covered under the umbrella of Ontological Uncertainty. The metaphor and concept of a Black-Swan event have received a lot of attention since 2007, and it is a present topic of research in science and finance. Black-Swans entered the limelight because of Nassim Taleb's book: *The Black Swan* (Reference [29]). Taleb categorized a black swan event as exhibiting the following characteristics: First, it is an outlier; it lies outside the realm of normal expectation, as nothing in the past can surely point to its likelihood. Second, it has an extreme impact. Third, human nature fools us into believing after the fact that the event was predictable, despite its outlier characterization. Since Taleb's initial exposition and discussion of Black-Swan events, other definitions have been proposed, all of which divide the spectrum under which these events are considered. For instance, Aven (References [86-88]) describes a black swan as a surprisingly extreme event relative to one's belief and knowledge. There are three types of events in the ontological category, based on the following definitions:

a. Unknown unknowns. Events, which were completely unknown to humans, i.e. Black-Swan events.
b. Unknown knowns. Events for which we do not have the knowledge, but others do.
c. Known and unlikely. Events that are known but deem very unlikely to occur.

The ontological classification encompasses all the events listed above (a, b, c,), tacitly assuming that it carries an extreme impact. Instances of the first type of ontological events are black-swan events. Examples are the unexpected effect of a new drug on the general population, the rise of the Internet and its consequences in the seventies, the Kennedy Assassination (except for the persons involved in the assassination), the quick collapse of the Soviet Union in the 1980s. Many of these events are explained away as deemed to occur after the fact, as discussed by Taleb, but what they all shared is the lack of prediction of the possibility of the event until it transpired. The second type of ontological events is illustrated best by our failure to consider or determine what others know. For instance, the September 11 terrorist attacks, Pearl Harbor, the Russian Rubble meltdown in August 1998, the Asian Emergent Bond Market collapse in 1997-98, the Battle of Midway (both sides knew it was going to happen, but nowhere the position of the opposing air-carriers was located). All of these events are easily considered after the fact, the signs were there, and some knew about it, but for most, they did not even enter their realm of thoughts, and even for those that did, they did not evaluate and consider their high impact. The last type of ontological events, "known but unlikely," is known to most, but the likelihood of their occurrence and the potential severe impact to the decision-maker are deemed infinitesimally small. Case in point, the tsunami that the destroyed the Fukushima Daiichi nuclear plant, the potential for a tsunami was considered, but never in relation to the destruction of roads and assistance to the nuclear plant, which lead to the significant impact of the tsunami. The collapse of the Real Estate and Financial Industry, in 2007-2009, can be potentially categorized as this type of event. Most investment companies did not model or considered the combination of effects in the market; assumptions were mainly driven by the behavior of the market from the past, all but a few thought it was “impossible” for the Real Estate market to collapse; our cognitive feelings blind us. In this latter sample, the following conditions no previously encountered together were at played: investment and real estate markets with double-digit growth for years, the high-degree of institutional leverage, and the liquidity of capital with loose lending practices among others. The past, as known at the time of the events, did not represent the future, these set of dynamic conditions were unique and their effects unknown and unpredictable to most. All, but few, ignored this possibility at great cost to their institutions and society.

Ontological uncertainty represents a state of complete ignorance in general. Not only do we not know, but also, we don’t even know what we don’t know. While the truth is out there, we cannot access it because we simply don’t know where to look in the first instance.

Summarizing, the characteristics of Ontology Uncertainty are:

- Un-knowledgeable events.
- There are three types of ontological events, with varying degree of ignorance.
- Highly impactful events and all deemed highly unlikely to occur; even in the cases, we are aware of their possibility.
- There is not a scientific framework to help to predict.
- The best course of action is to envision continuously worst-case scenarios affecting decisions under uncertainty and focus on measures to minimize the impact of any potential ontological event.

2.3.1.3 Uncertainty Categories and Spectrum

Delineating the different types of uncertainties assists understanding their variability, the ability or lack thereof for humans to predict them, and finally to focus attention in the areas of the uncertainty spectrum which historically have not been considered for forecasting and making decisions. The usefulness and awareness of this knowledge will vary by domain and the magnitude and potential impact of these extreme events. The criticality of the problem we are trying to predict for either economic, safety, environmental, or business reasons.

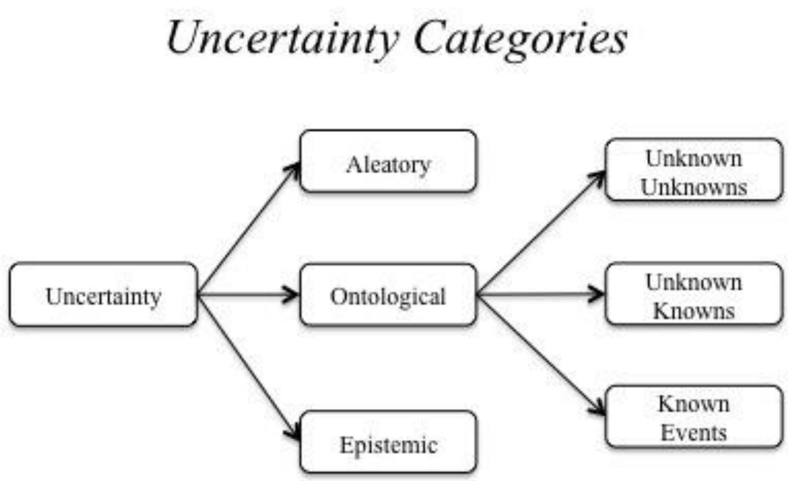

Figure 2.2, Uncertainty Categories

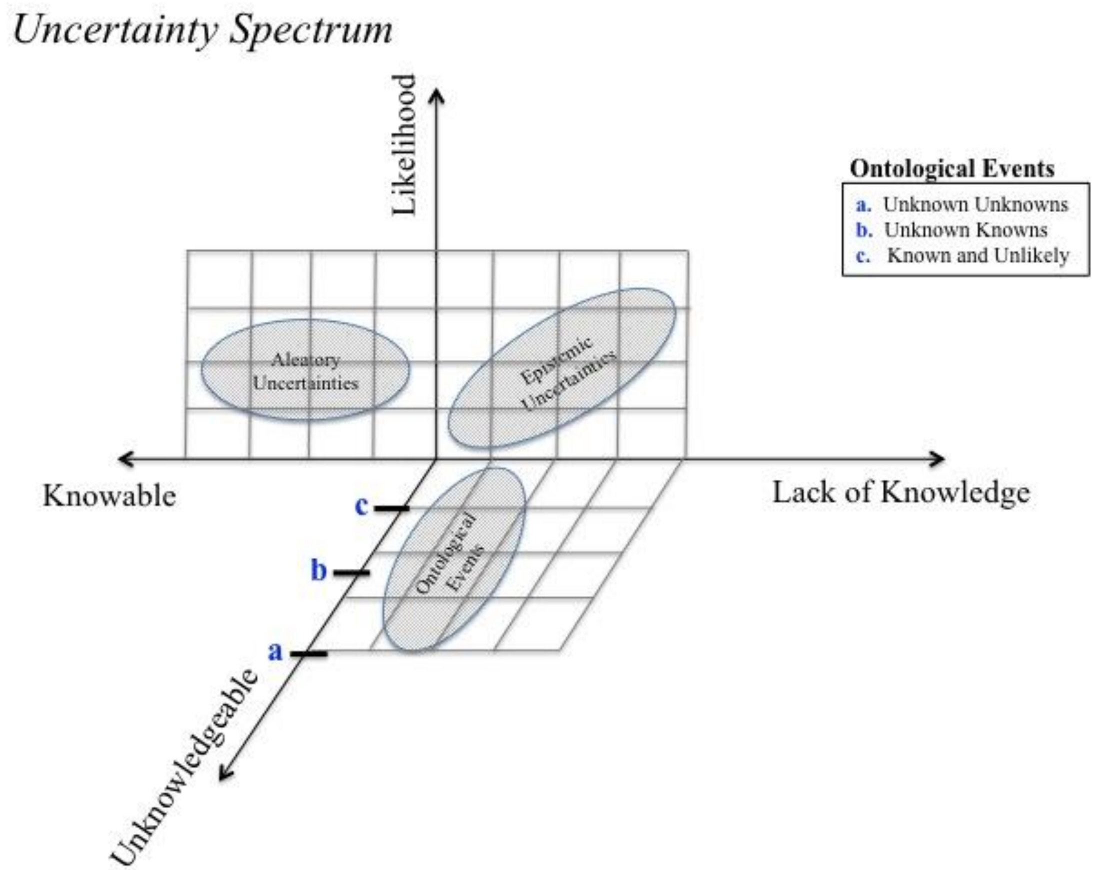

Figure 2.3, Uncertainty Spectrum

2.3.2 What is Variation?

Per the Oxford English Dictionary *"A change or difference in condition, amount, or level, typically with certain limits, i.e.: a) regional variations in house prices b) the figures showed marked variation from year to year"*. The term "variation" within QPMI refers to process variation, the randomness all processes operate under which is subject to statistical limits; variation is interpreted as defined by Walter Shewhart and W. Edwards Deming. Statistical Process Variation was the subject of research and investigation by Dr. Shewhart (Reference [40]), Dr. W. Edwards Deming [References 36-38, 43], and most recently by Dr. Donald Wheeler [46-49]. Variation, as described by Shewhart and Deming, consists of the randomness in all processes, randomness that can be inferred based on historical data of the behavior of the process. Process Variation is discussed in section 2.4.4.1, the focus within this section, is to elucidate its relationship to uncertainty, and why "Variation" is relevant to Portfolio Management.

A process is either stable or not, what defines this boundary? This was the focus of Shewhart's work in the 1920s. He empirically derived an approach to determine the thresholds, the limits for measurements in a time graph, taking at different time intervals, to infer the state of the process (see Wheeler and Shewhart for detailed explanation and derivation of the methods). Shewhart discovered that processes, in general, cannot be assumed to be homogeneous, i.e. their data is part of a particular probability distribution or juxtaposed set of distributions. Additionally, Shewhart logically deduced that the variation in any process can be caused by events from the different types of uncertainties (Aleatory, Epidemic, Ontological). Even so, Shewhart did not label the cause of the variation as such, Shewhart and Deming categorized process variation belonging to two types, Common and Special Causes per Deming (Chance and Assignable by Shewhart).

The relationship of the concept of variation to uncertainty is illustrated in Figure 2.4. The significant achievement of Shewhart's work is that he devised by empirical means a way to know if a process operational performance was within the Common Variation realm, i.e. within the expected randomness of the process, or due to a special event due to Epistemic or Ontological uncertainty. The goal of Shewhart's research was to devise a practical mechanism by which measurements of a process can be classified and measured. The results of such measurements aiding management in determining if Common Cause variation was acting upon the process (avoiding unnecessary and counter-productive intervention), or if the process was subject to a Special Cause event, something out of the norm. Special Cause events require investigation to assess the impact of such event and make sure their effect is removed from the process. This intervention is necessary to maintain the statistical performance of the process and most importantly to assure that the process stays stable, within the known statistical limits due to Common Cause variation. Shewhart concluded through his empirical research that a statistical un-stable process was unpredictable; no forecast can be derived from it, thus the great urgency to investigate and resolved any Special Cause event that affects a process.

Financial and Initiative Portfolio Management are subject to a variety of processes in the management of their assets requiring constant monitoring and analysis. For instance, on the financial side, what does the earnings of a given company tells us quarter to quarter? Is the volatility of the earnings within expected variation or subject to Special Causes requiring action? A similar question can be applied to other financial metrics such as stock price, management stability, corporate bond rating, sales, the number of customers, etc. In QPMI, there are different set of metrics for the processes operating internally and externally upon an initiative and the whole portfolio. A representative list includes: The probability of success for delivering an initiative within a time frame, cancelation likelihood for an initiative due to any number of factors (internal, external forces, etc.), the volatility of the expected value to be gained from the initiative over time and corresponding statistical variance in the probabily of achieving the named expected value, etc. The delineated metrics are part of an initiative execution and analysis processes, the metrics are not single number estimates, but random variables represented by their non-parametric distribution functions, cumulative distribution function (CDF), and Entropy derived empirically based on Bayesian and Monte Carlo stochastic models.

Additional dynamic attributes of a portfolio are characterized by time series; these are the same metrics discussed previously, but analyzed from the potential impact of time upon them. How are the metrics for the processes trending over time? This question is at the core of Statistical Process Control (SPC) theory and it is critical in the analysis of executing initiatives to make a fully informed decision regarding which initiatives to execute or keep executing with the limited funds and constraints all individuals and organizations have. The statistical time series analysis also provides one of the cornerstones of Continuous Improvement in LEAN organizations. Knowing if the process "is not" statistically stable, should prompt management to focus attention immediately to resolve the issue, failure to do so per Deming and Shewhart means that any previous forecasts regarding completion, value creation, etc. are not valid. Only processes that are statistically stable can be predicted, no if and buts about it, disregard at your own peril. Another benefit at the portfolio level, monitoring the overall status from a statistical control point of view provides insights as to how underlying initiatives are performing and macro level monitoring of the system under which they execute. For instance, consider the following scenario: A portfolio is known to have historically, 20 to 30 percent of the executing initiatives, in a state of chaos, in terms of statistical control, and then over a course of a few weeks, the number increased to over 50%. The dramatic changed in statistical performance should be a clear signal to management, that at the macro level something significant has changed. Failing to investigate and remediate the cause or causes ignores the key finding from Deming, no process is predictable if it is not under statistical control.

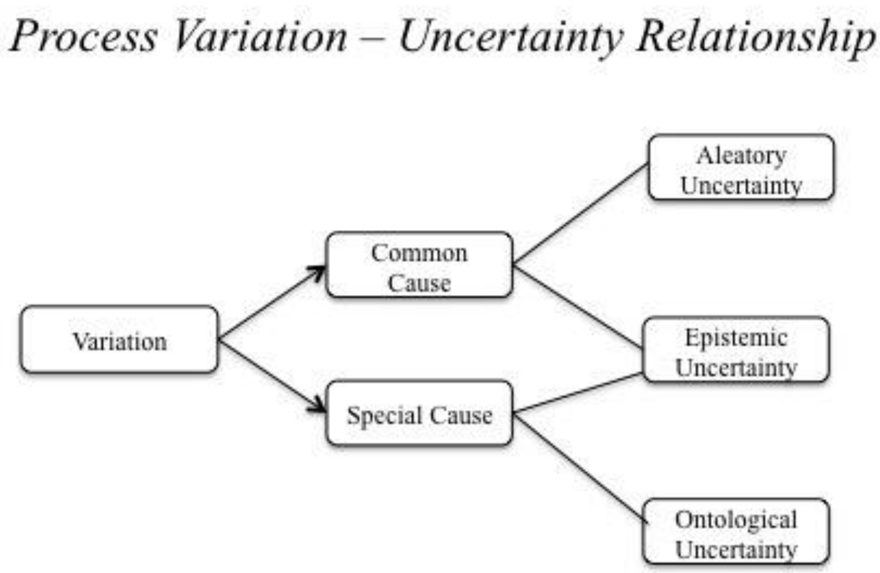

Figure 2.4, Process Variation – Uncertainty Relationship

2.3.3 What is Risk and The Dire Consequences If it is ignored?

The word “risk” has different meanings and connotations. The intention of discussing risk is to frame its link to uncertainty, process variation and ultimately with decision-making under uncertainty. Furthermore, it is necessary to define what it is meant by risk at the portfolio, initiative, program, and project level. The desire to provide clear definition and methods is required for establishing an operational framework similar to the ones in the financial industry. The financial sector is subject to governmental regulations and internal risk management procedures. The goal of these management efforts is multi-level; first to make sure the company adheres to legal regulations and internal solvency rules; secondly, facilitate a pro-active understanding of the risks to new and prospective investors of a financial portfolio as well as the executive officers in an investment or banking institution.

The risks to a portfolio of initiatives should not be considered any less important than financial portfolios. The benefactors of a portfolio of initiatives are the stockholders and employees of an organization, and the “portfolio risk” can span from minimum to monumental to the viability of the enterprise and consequently to its valuation and long-term existence in public markets. The ability of a corporation to manage initiatives as part of a portfolio based on their financial and strategic goals for the short, medium, and long-term prospects ought not to be left to chance. The portfolio represents the living strategy of a company, and lack of planning and analysis implies relying on randomness for success. Would the reader consider investing in a financial portfolio, whose selection of assets is left to the opinion of Security Analysts, without any process and procedures to measure and quantify the potential value and volatility? In a global economy, with the exception of monopolistic industries, the odds for failing will catch up with any company. In financial portfolios, it is expected that risks are measured quantitatively and qualitatively, regulations are always evolving. The recent events of 2008 reminded investment and banking institutions the need to continue to update their models. In the financial sector, Epistemic and Ontological Uncertainties were not considered in the majority of companies, models focus primarily on Aleatory uncertainty, heavily relying only on historical data for extrapolating what the future will be, with limited if any consideration to the complexity and uniqueness of the future. Additionally, the correlation effect assumptions between assets proved to be wrong, correlation turned out to be non-linear depending on the degree of volatility of the markets. Many Investment Banks were bankrupted or acquired during the financial crisis of 2007-2009 (See Reference [92]), notably Lehman Brothers with over 100 years of operation. Now consider the survival statistics of companies in the S&P 500, refer to Figure 2.5, from a 2012 article by Richard Foster (“Creative Destruction Whips through Corporate America, “Reference [93]). The article provides a great insight into the turned over rate of organizations, especially, the accelerating trend regarding the average lifespan, and the broad spectrum of companies that have disappeared. The following summary statistics, directly quoted from Foster's article, owed to be considered when deciding if portfolio management for initiatives and quantitative methods for decision-making and risks are not worth the trouble.

1. *US corporations in the S&P500 in 1958 remained in the index for an average of 61 years. By 1980, the average tenure of an S&P500 firm was 25 years, and by 2011 that average shortened to 18 years based on seven-year rolling averages. In other words, the churn rate of companies in the S&P500 has been accelerating over time (see chart below).*

2. *On average, an S&P 500 company is now being replaced about once every two weeks.*

3. *At the current churn rate, 75% of the S&P 500 firms in 2011 will be replaced by new firms entering the S&P500 in 2027.*

4. *In 2011, a total of 23 companies were removed from the S&P500, either due to declines in market value (for instance, Radio Shack's stock no longer qualified as of June) or through an acquisition (for instance, National Semiconductor was bought by Texas Instruments in September).*

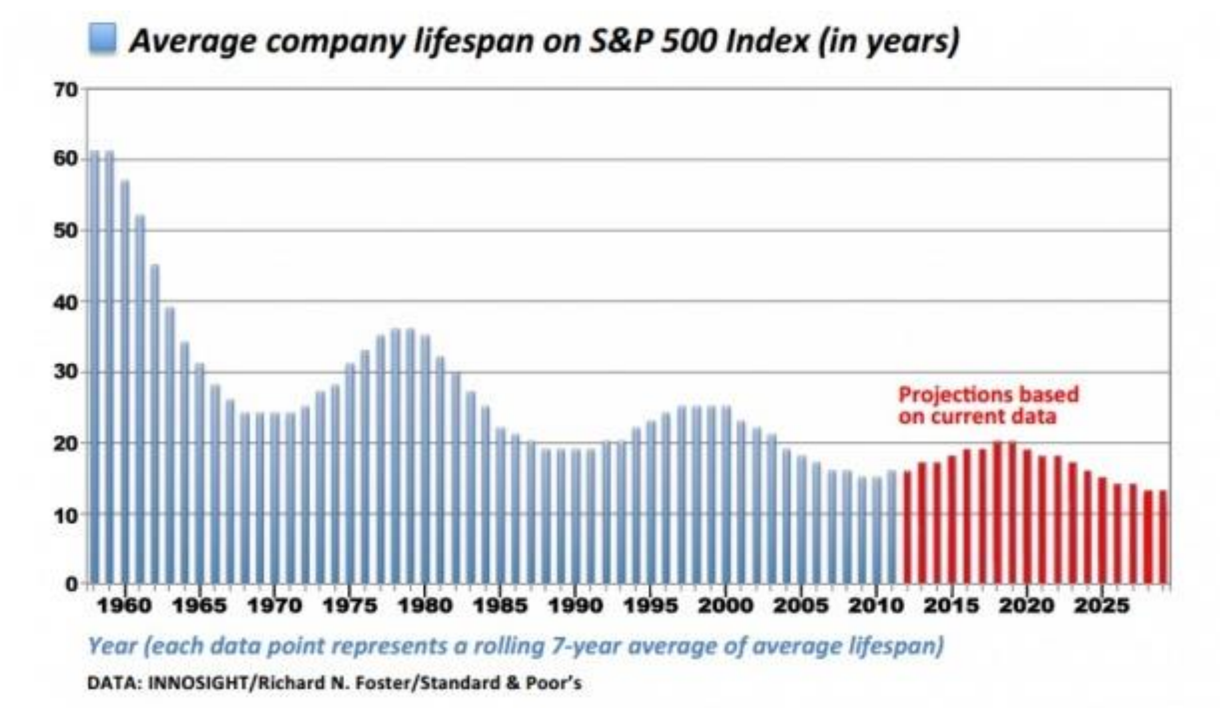

Figure 2.5, Average company lifespan on S&P 500 Index

The statistics and accelerating trend of churned over, demands the question, why? There could be many reasons, the global economy, the effects of the technology revolution, etc. The data should motivate organizations now more than ever to maximize the plausibility of making the best decisions, the decisions that create the most value in the short, medium, and long term, with the best likelihood of succeeding within the risk tolerance of the company. The cost of being wrong is most probable extinction (per the data, in average about 18 years, and in competitive industries one can safely assume a much higher turnover rate). The organizations that embrace systematic decision-making and analytical portfolio management techniques, considering all types of uncertainties, should have the better odds of surviving. Depending on the wisdom of a few, to make the right choices, it is similar to the fatal mistake of believing in prodigious stock pickers, investment marketers, etc. Believing that because some people make the right investments-choices for a few months, even years in the past, it does not necessarily indicate skill level, but just the law of large numbers applying to brokers. A few will be successful for a while, bound to happen, but most, will not beat the market averages over the long-term. Taleb Nassim discusses this topic at length in its book Fooled by Randomness (Reference [85]). Even so, his sample scenarios are market driven, the analogy to decision-making inside a corporation is direct, both worlds must make decisions subject to uncertainty, and in the case of initiatives, there is not historical data to leverage as an initial reference point. Studies have been conducted regarding business executives making decisions and the success rate of those decisions, the results fared at no better than flipping a coin. How many years can a company expect to survive making decisions that on average are right only half the time, or worst at a quarter of the time? Do companies even known how often their hypothesis regarding the value creation from initiatives turned out to be correct?

The used of the term "risk" in association with classical probability was first established by the economist Frank Knight, in his classic 1921 book "*Risk, Uncertainty, and Profit*." In his work, Knight equated risk to the odds associated with the Frequentist's interpretation of Probability Theory, that which is derived from the game of chances, or repeated exact experiments. At the same time, as typically happens in science and mathematics, the economist John Keynes published his classic book, "*A Treatise on Probability*," his insight into risk and association with probability was that as a measure of belief formulated on evidence. Both men, associated "risk" with the objective interpretation of probability, as discussed earlier, randomness due to Aleatory Uncertainty. Yet, the two famous economists perceived that uncertainty embodies something more than risk entailed; risk is just but one aspect of uncertainty, a point that can be clarified by a consideration of Epistemic and Ontological Uncertainties. Yes, "risk" in the financial and economic fields ignored this aspect of uncertainty, until the recent present, even so, Knight and Keynes, famous economist warned about it almost a century ago. The purpose of this discussion is to make the reader aware that the conventional understanding of risk is that associated with only one aspect of uncertainty, that which is only within the Aleatory domain. Why does it matter? It matters as pointed out by Frank Knight; he cared about uncertainty in decision-making, that which is out of the scope and consideration of standard risk evaluation. Ignoring the risk introduced by Epistemic and Ontological uncertainties is fooling oneself into a false sense of security regarding the degree of perceived risk in a decision, be an initiative or financial asset investment.

Making decisions in QPMI requires consideration of Epistemic and Ontological uncertainties, not just in the Aleatory spectrum. How do we know that an initiative will generate the value hypothesized and what is the likelihood? How probable is it for an organization to deliver a complex initiative that has never been done before within a market-demanded time frame? What are the chances the initiative is forced to be canceled due to any or all the following causes and data:

- Market forces.
- Technology changes.
- Insufficient funding.
- New attractive initiatives.
- Environmental factors.
- A change in government regulations
- The complexity of the endeavor.
- Ability to deliver within a time period.
- Missed window of opportunity.
- Organizational strategy and alternate or modified goals.
- Company and historical industry data regarding cancellations.

The above aspects involve in the decision-making process are encountered when choosing among initiatives. They ought to be considered, as they affect the expected value creation for any investment. The questions what are the risks for a project, program, initiative, and the portfolio must be examined and defined for exact meaning and definition to provide context as to how a portfolio analyis for initiatives addresses them, and equally important to provide a common vocabulary and parameters to assess the value and volatility of the portfolio.

Risk is a word, not a number. A view shared with Ricardo Rebonnato (References [82,83]). The question what is the risk of the initiative, decision, program, and portfolio cannot and should not be reduced to a number, a magical number-indicator derived from the aggregation of other numbers. Also, there might be aspects of the decision-making that forces qualitative analysis; this is the scenario when there is no evidence and experts; or it is impossible to quantify the uncertainty of a negative event with tremendous consequences, black-swan events. Furthermore, there are cognitive aspects in regards to decision-making under uncertainty that cannot be represented by a number. The cognitive biases are better addressed with questions that force the decision maker or evaluator of a portfolio to assess the risk of the object in mind from multiple angles, and then and only then, making the decision or ranking of initiatives.

The uncertainty-risk relationship is represented in Figure 2.6. It can be observed that all the different type of uncertainties can potentially introduce risk. Probabilistic measurements can be computed in some cases (Aleatory and Epistemic), but no for Ontological, only qualitative valuations. The fact that ontological uncertainty does not provide a number or numbers for comparative analysis, does not mean, a qualitative assessment of the uncertainty to the decision maker as an additional consideration; it is not valuable. For example, consider a company developing a product for the Asian Market; an analysis of future demand, pricing, competitors, and other factors has been conducted. Thus, allowing subjective (Bayesian Analysis) probability derived regarding the odds for the creation of the future value. Furthermore, an analysis regarding the cost and development uncertainty has also been fully developed. At this point, the enterprise can choose to end the analysis, but this could be a big mistake. How so? The future of the Asian Market and buying power sustainment may cease to exist or be drastically reduced. As of May 2016, there is uncertainty surrounding the economy in China; there is uncertainty regarding the consequences of the general election on trade with China to name a few notable concerns. What if you were the decision-maker and considering an initiative to develop the discussed product at a cost of $10M, $100M, $1B? Would you embark on this initiative? How would you communicate the risk? Can your company survive if things go completely south, i.e. the Asian Market economies collapse for multiple years? Now consider the following choice, the option to fund another initiative in a whole different market, but the expected value generation, it is only 25% of the Asian option (ignore the variance and higher moments for simplicity of argument for now). Furthermore, from a qualitative and quantitative assessment (Market analysis, economics' forecasts, etc.), this latter option is not considered nearly as likely to collapse in the next 10 years as the Asian market. The findings estimate a 10 to 1 odds of the Asian economies collapsing compared to the market for the other initiative. What would you do? Would your answer change if the odds were 20 to 1 or 5 to 1? It is these types of evaluation scenarios that force upon us the consideration of quantitative and qualitative aspects of risks and their consequences. It is the combined examination of all aspects of risks, quantitative and qualitative that provides the overall perspective, and demands a review of all scenarios to make a sound and comprehensive decision. The reader might consider the illustrated example extreme, but it was only done to emphasize clearly and dramatized how risk is just more than one word and the importance of the qualitative and quantitative aspect of analysis if the decision analysis demands it. For many initiatives and portfolios, evaluation within only the Aleatory and Epistemic uncertainties are all that is required, but for others it is not. One must be aware of Ontological uncertainties and conduct a qualitative and quantitative assessment assuming the impossible might happened. Black-swan events have occurred through history, and the only known is that they will continue to occur, when and where, nobody really knows, yet we can imagine worst case scenarios and try to determine if the consequences can be lived with.

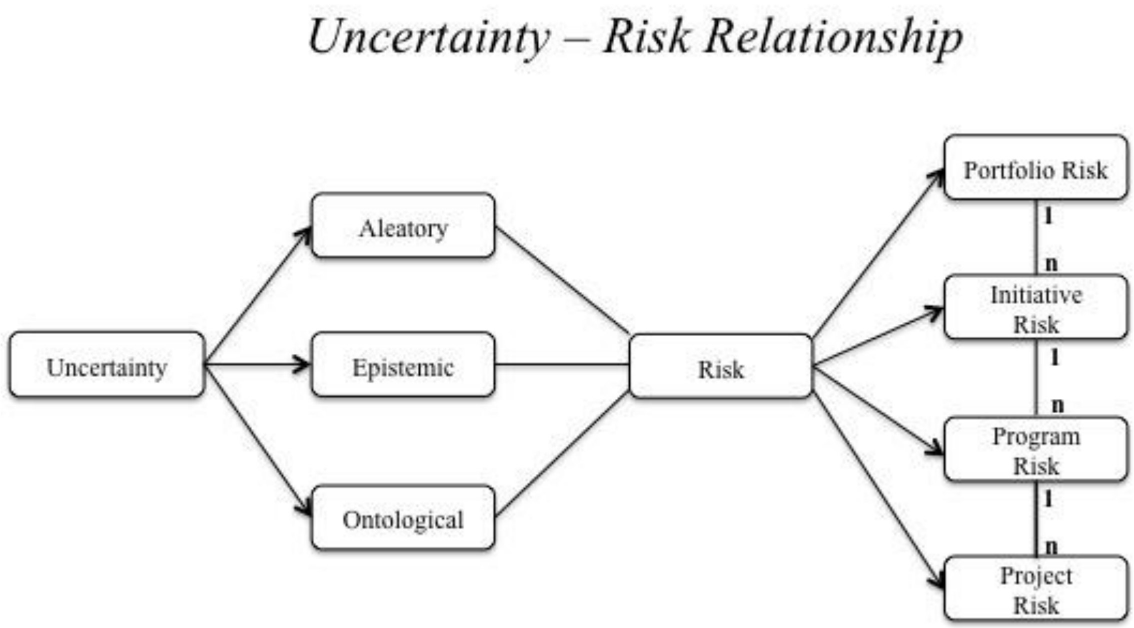

Figure 2.6, Uncertainty – Risk Relationship

2.3.3.1 QPMI Risk Assessment Methodology

The methodology for risk evaluation and portfolio analysis in QPMI is based on the approach initially proposed by Harry Markowitz in 1959 for financial portfolios. Markowitz associated risk with two factors in a financial portfolio, the variance of the price of an asset and the correlation between assets of a portfolio, correlation defined with the literal meaning from Probability Theory, the degree that one asset's behavior moves directly or opposite to the price of another asset in a portfolio. Markowitz's approach is generic and sound; he won the Nobel Prize in Economics in 1990 for his work on Portfolio Management. The key concept behind his theory is to equate risk with the volatility of the prices of assets (stock or bonds), and the correlation of the prices within assets. The more diversify the portfolio is, investments in different industries that are autonomous and behave differently under different economic conditions, the lesser correlation and consequently the smaller the overall volatility of the portfolio. There have been many modifications and extensions to Markowitz's work; however, they compromised mainly enhancements, tweaks, on top of his original work. For instance, Capital Asset Pricing Model (CAPM), consideration for different type of assets, additional portfolio constraints, inclusion of third and fourth moments to the original quadratic equations derived by Markowitz, inclusion of other investment vehicles (derivatives, short and long positions, etc.) allowing further diversification of risk. One particular extension closely related to the needs of a portfolio management of initiatives, it is the work by Ricardo Rebonnato (Reference [82,83]) that extends Markowitz's framework to address other types of risks introduced by Epistemic and Ontological uncertainties. The concepts behind Rebonnato's work are very similar to the ones utilized by QPMI; they both aim to include other type of uncertainties in portfolio analysis. In the case of QPMI, it is absolutely necessary, since most initiatives do not have a historical data set to draw initial points of references, initiatives consist mainly of knowledge work, which are always different and subject to all type of uncertainties.

The methodology for assessing overall risk in QPMI consists of eclectically leveraging Markowitz's Financial Portfolio methodology and extensions to his work, namely:

- Rebonnato's inclusion of Bayesian Analysis.
- Prospect Theory.
- Decision Science.
- Statistical Process Control.

- Multi-Criteria Decision Analysis (MCDA).
- Entropy (Shanon, E.T. James, and Kullback–Leibler divergence), among others (see References [14,96,97]).
- Chaos Theory
- Non-linear concepts of statistical methods for modeling correlations among initiatives.
- Bayesian Networks.

Risk assessment within QPMI consists of addressing and answering the following:

1. **Given an initiative, what is the expected return – prospective value creation, and quantitative analysis for the following risks:**
   - There are multiple categories of risks at the initiative level; all must be evaluated and quantify separately to apply in the portfolio analysis:
     i. **Cancellation or Failure Risk**. The probabilistic estimate for canceling an initiative or for the initiative failing to complete for any reason.
        - The assessment of this risk is vital to calculate the expected value of the initiative. Consider the stereotypical gambling example for illustration, a toss of a coin and a die throw, for the same bet, they both have different expected values due to the probability of your desired outcome no occurring. In the case of initiatives, most of them have a chance of failing and experienced severe challenges. Data from the 2015 Standish Chaos Report puts the "average" failure rate for 2015 at 19%, but depending on the initiative size, project management methodology; the actual range is between 9 to 42% (Reference [94]).

     ii. **Value Risk.** Risk due to the variance in the probabilistic distribution of the potential value hypothesized upon completion of the initiative, and the effect of other initiatives.
     iii. **Cost Risk.** The variation associated with the different costs to develop and operationally managed an initiative upon completion. The cost estimate is not a single number, but a range, with a probabilistic distribution.
     iv. **Duration Risk.** The variance in the schedule to develop the initiative.
   - Value creation is the estimated value to be created and corresponds to a probabilistic estimate.
   - Value, as defined in this context, corresponds to the economic concept of "utility," for initiatives with multi-attribute benefits. MCDA methodologies such as MAUT or one of his derivatives must be employed to determine in a normalized manner the initiative's utility.
   - The variances for the value, cost, duration, and cancelation-failure rate are another inherent risks present in an initiative.

2. **Define the statistical correlation between all initiatives under normal and extreme circumstances.**
   - For the value creation and cancellation aspect of the portfolio analysis.

3. **Define the time period over which the value will be created.**
   - The probabilistic estimate corresponding to the amount of value created per time period.

4. **The statistical stability – volatility – of the prospective value and all risks for an initiative over time.**
   - Are the probability distributions for the different parameters stable or chaotic?
   - What is the trending state of stability of the parameters?

5. **Account for cognitive biases and findings from Prospective Theory**
   - Incorporate different utility functions for the positive and negative aspects of the decision-making process.
   - Define multiple utility functions for the same attribute, if the range of values varies significantly. Prospect Theory shows utility is non-linear in the sense that a utility for a given

range of values, may be different for larger or smaller ranges; the utility curve depends on the degree of magnitude of the values.

- Address the cognitive part of the decision-making process and biases to rational decision-making exposed by Prospect Theory, by answering the following questions:
    - i. Can we afford to commence on this initiative if things do not eventuate as planned?
    - ii. Can we survive the initiative failing, the worst possible outcome?
    - iii. What is our ultimate loss tolerance?
    - iv. How does the risky initiative look in this light?
    - v. If everything does work out in the best plausible manner, how much better can I realistically hope to fare than if entered a risk-less investment? In another words, is the rosiest scenario worth the risk I am taking?
    - vi. By how much would things have to go wrong before the risky initiative performed no better and no worse than putting the money in a safe deposit account?

6. Define a handful of indicators for quantifying risks in an initiative.

- Indicators associated with the way we react to risk. They will allow us to understand whether we are selling lottery tickets, buying insurance, or rolling dies.
- Do not combine indicators thus identified into a single "decision indicator" -- no magic formula. Choices come first and from this a utility function or decision rule. Help and guidance translate into decision consistency.

7. Sensitivity Analysis.

- Quantitative analysis.
    - i. How sensitive are the results – indicators to?
        - a) Slight changes to the utility functions?
        - b) Timing assumptions?
        - c) The volatility from measurements-analysis at different time periods?
- Qualitative Scenario Analysis.
    - i. Is the initiative sensitive to ontological uncertainties? If so, which potential events? And what are the worst consequences should these types of uncertainties arisen?
    - ii. Can the negative ramifications of these ontological events be mitigated? Minimized by pro-active actions? If so, what is their cost and how certain (based on what subjective analysis?) are we that the pro-active actions can minimize or avoid the negative impact of a black-swan event?

8. Entropy

- The concept of entropy will be discussed in section 3. Suffice to state that entropy is a way to quantify the degree of uncertainty in a random variable. Depending on the type of distribution, entropy might better represent the amount or lack-of-knowledge from a distribution. The association of entropy with variance is not necessarily linear. The Differential Entropy values should be determined for all initiatives:
    - i. The entropy of the Value Distribution for each initiative.
    - ii. The entropy of the Cancelation Distribution for each initiative.

A work of caution regarding only associating risks to variance. A large variance is not necessarily a negative attribute; it depends on the variance of the actual values; there could be limited or no negative downside. Variance itself does not differentiate the latter situation from its opposite baneful effect. The variance whenever possible should be examined with an understanding of the higher moments of the distribution, e.g. the symmetry, skewness, and kurtosis. The skewness of the distribution tells us the shape of the distribution, where most of the density is concentrated; the kurtosis will give us an indication of the fatness in the details, this is important to assess the extremes on the estimates and consequently how they may impact the decision-making.

2.3.3.2 Risk Types

2.3.3.2.1 Project Risks

Project risks are sorted under two main categories. First, those that can cause delays and costs variances. Second, risks that can cause the project to be canceled for any reason. A project in QPMI is considered a single atomic unit of execution.

2.3.3.2.2 Program Risk

A Program is a set of one or more projects and programs that must all be delivered together. Program risk is the mathematical convolution of all the different risks in all the projects and programs. The overall program risk determines the probabilistic value, cancellation, duration, and cost from its entire components combine.

2.3.3.2.3 Master Program Risk

A Master Program is a set of one or more projects and programs that must all be delivered together for value to be realized, this latter concept, it is the key differentiator with a regular Program. Master Program risk is the mathematical convolution of all the different risks in all the projects and programs making up the master program. The overall master program risk determines the probabilistic value, cancellation, duration, and cost from its entire components combine.

2.3.3.2.4 Initiative Risk

An initiative may be composed of one or more master programs, all of which are mutually exclusive. See Figure 3.2, 3.3, and 3.4 for examples. Based on this definition, Initiative Risk is the convolution of all the different risks of all master programs that compose the initiative.

2.3.3.2.5 Portfolio Risk

There are three macro areas of risks to an initiative's portfolio. First, it is the execution performance of initiatives under development. Second, the future value creation expectation and variance, and third, the cancelation-failure risk for initiatives in the portfolio.

1. Execution Performance
    a. Overall cost variance of all executing initiatives and the statistical stability of the trend over time.
    b. The probability of success for each initiative to meet current plan dates and the statistical stability of the trend over time.
2. Value Creation
    a. Overall expected value creation of the portfolio versus variance over time.
3. The Cancelation Risk of initiatives across the portfolio.

2.3.4 Embracing Uncertainty as the Catalyst of Future Performance

Uncertainty is a fact of life and business, most organizations and people tend to ignore uncertainty rather than deal with it, much less use it to their advantage. Uncertainty can be a competitive advantage for those firms who understand it and manage it better than their competitors. Every analysis involves some level of uncertainty and requires us to make some assumptions about the risk of the venture. The key is whether you are making explicit assumptions using statistical analysis or making uninformed guesses. Embracing uncertainty as a fact of making decisions can minimize many surprises or bad outcomes.

Probability Theory is the primary mathematical framework used to manage uncertainty, and Chaos Theory to a lesser extent. There are two different interpretations of probability as applied to problems of forecasting with uncertainty: The Frequentist and Bayesian approaches. The Frequentist view applies to experiments (requires the ability to repeat/sample the experiment), Bayesian methods are applied to all inference and problems with uncertainty, and no limited to conducting the exact, same experiment under the same conditions to be applicable.

Uncertainty, as it relates to portfolio analysis of initiatives, should be managed with Bayesian Analysis and simulation techniques, since there is little or not historical data for a given initiative or ability to repeat it many times. Most corporate initiatives are one-of-a-kind endeavors requiring knowledge work with high degree of uncertainty in many areas. The root mathematical approach employed by Decision Science is Probability and Economic Utility Theory, and for management and understanding of processes, it is Statistical Process Control (SPC) theory. Additionally, the decision-maker should be aware of the cognitive biases influencing the decision-making process and complement standard Decision Theory and MCDA methods with Prospect Theory.

2.3.5 Initiatives and Uncertainty

Initiatives are subject to different types of uncertainties; knowledge work is empirical, in the sense that we cannot pre-determined exactly what we need to create, it is characterized by multiple stages that involve conceptualizing, designing, implementing, testing, iterating. The empirical attribute for knowledge work is due to the underlying complexity of the system to be created and invented, and the measurements of our progress along the way, the path from beginning to end, it is uncertain and in some cases, even the feasibility of the initiative is unknown. It is a fatal mistake in judgment to ascertain a single point estimate for any project as an accurate assessment of reality; just because it is written down on paper or a PowerPoint document or a project plan, does not make it any more real. IT work, especially software development and any one-of-a-kind endeavor are subject to epistemic and ontological uncertainties. Typical, but no exhaustive, list of challenges afflicting large IT custom development or Commercial-off-the-shelf projects:

1. Software development is a discovery process; many of the assumptions made in the planning phase, quickly become obsolete during development; this is also true in large COTS projects, given the level of customization, integration, functionality behavior expectations and exact usability and purpose.
2. Integration and testing tend to uncover significant issues late in the process, which results in frequent and costly schedule slips and working teams to death. Typical representative scenarios include the following:
   - Performance, Quality and Integration issues.
   - Need to re-architecture applications.
   - Discovery that significant functionality is missing.
   - Requirements believed to be crystal clear in the planning phase found not to be and requiring additional work to remediate functionality gaps.
3. No accounting for risks to the project in the planning schedule.
4. Changes in the market and business environment, for multi-year initiatives. Priorities shift and scope changes to functionality are the norm, not the exception, thus the necessity for changes to the scope of the project.
5. Estimates of planned scope are deterministic and do not consider the epistemic or ontological uncertainties in the development of functionality of a project. More often than not, it is not known what is really desired until you develop a version to review and subject it to analysis by the users of the system.
6. Quality control and the rate of creation and fixing of bugs is another major challenge that significantly affects planning and scheduling.
7. Multi-tasking (due to competing priorities) and the exponential negative impact of unmanaged Resource Loading for resources on the duration and cost estimates.

Initiatives' development processes are subject to variation from Common and Special Causes (see section 2.4.4.1). Common Cause variation is existent in all processes (e.g. software development, new physical construction). Even systems that seem repetitive in nature are subject to Common Cause variation as a result of resource availability, modifications to a system, etc.; all tasks and events in life have a degree of randomness attach to them due to the underlying Aleatory Uncertainty. The other type of variation encountered in all knowledge work is Special Cause variation; this variation can be thought of as known and unknown events that might impact the outcome of an endeavor. Underestimating these events and their effects on planning results in cost overruns and unreliable schedule planning. It should be considered critical to understanding what process variations might affect an initiative and their potential impact on schedule and cost.

In the Agile world, it has been learned that planning accuracy, for knowledge work, does not increase linearly with the amount of time dedicated to the activity, even for two-week sprints. Accuracy quickly reaches a point of diminishing returns; you never reach 100% even if you spend an infinite amount of time planning. The reality of knowledge work is that as you develop, you learn and adjust; no planning can anticipate these realities, complexities encounter during custom software development and enterprise projects leveraging off the shelf applications, for the same reasons previously explained.

To gain a better understanding of uncertainty in initiatives due from all causes, it is necessary to simulate potential Common and Special Causes and consider any relevant historical data and expert information that may provide subjective knowledge which may impact the forecast. Simulation is the domain of Stochastic Processes and Monte Carlo Analysis.

Other areas that have a high degree of uncertainty in initiatives, it is the expected value to be created; revenues, market size, product effectiveness, compliance, safety, customer satisfaction, represent a sample of the range of tangible and intangible benefits typically associated with initiatives. Furthermore, the uncertainty linked to the generation of value has a timing factor, for many initiatives, the derived expected value will diminish with time.

Many organizations have institutionalized risk management and processes and policies within project planning and execution to manage uncertainty. However, risk management for initiatives is often little more than a yes or no answer to "Should we accept the risk?" Risks are often viewed as "intangible" and described using qualitative terms such as "likely" versus "unlikely" and "significant" versus "insignificant." These descriptive adjectives are insufficiently precise and mean different things to different people, research in this area by Daniel Kahneman (References[1,2,54]) and O`Hagan (reference[77]) shows the degree of ambiguity in the interpretation of these adjectives, for one person or multiple people. For example, a lower-level manager might have a very different interpretation of what qualifies as a critical risk compared to that of a CFO or CTO. Failure to describe and understand all risks and the effect of time upon them, coupled with initiative-by-initiative decision-making, creates problems for risk management; the latter concern directly relates to the effect of correlation to initiatives in a portfolio, which can introduce a domino effect upon the failure of a given initiative on others. Given enough risks in an initiative, even if they are unlikely to occur, the uncertainty in future events and complexity in software systems, risks will trigger, however, unlikely they may appear; if it is not a known risk, one that you were not able to anticipate. The consequences of risks in software development projects and Commercial-off-the-shelf (COTS) implementations vary in impact depending on the risks, from very low to very high. Understanding these low and high impact qualitative descriptions regarding schedule, cost, and value creation should be quantified probabilistically; the analysis may result in re-prioritization, resource re-allocation, or abandoning of the initiative.

For illustration, consider the following hypothetical scenario regarding risks in an IT software development initiative. What are the probabilities of success for the following initiative? An initiative with two master programs, each one with two projects, and each project with five known risks; each known risk is independent of one another, and each with a five to ten percent probability of occurrence (based on subjective expert opinion or prior historical data or both). Each risk has an estimated impact on the schedule and budget varying from 10% to 50%. What is the potential impact to the schedule if you consider the risk scenarios defined and assume the current initiative schedule has an estimated 80% probability of success? What would be the implications for the cost considering the risks? In order to ascertain and estimate answers for the initiative described and similar one-of-a-kind initiatives, one should utilize Probability Theory and Stochastic Models to quantify the probabilistic impact on delivery and cost.

In summary, failure to consider risks in forecasting do not make them go away and your probability of success subsequently to increase. The most accurate way to forecast schedule and budget for an initiative is one that includes all type of variability and considers known risks and their corresponding probabilistic impact. For unknown risks, historical data can be used to estimate their number and potential impact, and if that data does not exist, then one can choose either eliciting expert opinion to quantify or industry trends or both.

2.4 Foundational Methodologies and Theories for QPMI

2.4.1 Decision Analysis Science

How do you define Decision Analysis? Two commercial definitions are 1) "Decision Analysis (DA) Science is a management methodology and set of probabilistic frameworks for facilitating high quality, logical discussions which illuminate difficult decisions and lead to clear and compelling action by the decision maker. - *Reference [9]"*. 2) "The process of filtering, optimizing, and organizing mined information to support decision making." *McGraw-Hill Science & Technology Dictionary*. Decision analysis originated in the sixties by Dr. Ronald A. Howard, professor of Management Science and Engineering at Stanford University; where he still currently teaches; and Dr. Ward Edwards, who passed away in 2005.

The purpose of DA is to utilize systematic thinking to connect current and future situations. All decisions you make today involve some action to be taken in the future. One should understand the structures that are present today and how they change in the future. Furthermore, entities and rational humans ought no fall into the trap of underestimating future responses or changes in underlying systems. Decision Analysis is an enabling discipline to QPMI; DA is leveraged for evaluating new candidate initiatives to a portfolio and then for analytical comparison to other initiatives in the portfolio (in the queue or an executing state). The ultimate goal of employing DA Science and Modern Portfolio Theory is the determination of the optimum set of initiatives to execute for maximizing value for given degree of risk tolerance, subject to constraints and strategic goals within an organization.

One of the goals for DA is making rational choices using the laws of rationality and probability theory and no based on cognitive behavior, which is subject to a number of heuristic biases which lead to sub-optimal rational decision making, and consequently value creation. Increasing the odds of making the right choice should be a priority in order to optimize value creation. The rational understanding of why a decision is made leveraging a quantitative and systematic set of processes and frameworks that provide clarity, accountability, and reproducibility of the decision-making criteria is of tremendous value. A systematic process invites rational thinking behavior and openness to investigate and derived the optimum set of initiatives, which presently are primarily chosen on intuition and political savviness of the sponsors. It is enlightening to review the findings on results of business decisions in general. In a recent survey done by Paul Nutt at the London Business School, he found that fewer than 40% of business decisions made without a structured collaborative decision process are successful (his criterion for success was the decision stayed in place for a least two years). A survey by the American Management Association found that most business people only make the right decision about 50% of the time, same as the random chance of flipping a coin. So what does this empirical data tell us? Uncertainty is a play, based on the complexity of the decision; it might be a costly mistake to any organization to choose on intuition, which is subject to judgment errors and heuristic biases (discussed ahead).

All decisions do not need to go through a DA process if the decision is clear or the cost of failure is not significant. However, parts of the DA process and methodology are essential to be able to evaluate and compare different initiatives from a value and risk perspective, using probabilistic analysis. For example, consider a company with enough funds to execute only on one of two large initiatives; schedule and costs are estimated the same for both, and sponsors for each initiative state the value generation to the company will also be the same. Which one should the organization choose and why? The sample scenario described, is the type of business situation address by DA and in need of a solution by an effective initiative portfolio management system; another critical use case of DA in QPMI is selecting which initiatives to execute from a set of the queue and in-development alternatives.

DA is an evolving science, as the mathematical tools become more feasible to use from a computational power standpoint, more complex and realistic scenarios can be modeled leveraging Monte Carlos models, Bayesian Analysis (Bayes Networks) and Markov Chains for very complex business decisions. DA traditionally uses Influence Diagrams and Decision Trees as part of their analysis, but these methods can be substituted by Bayes Networks or Multi-Level Bayesian Analysis or both to simulate more realistic scenarios. The decisions for what modeling to use are uniquely dependent on each situation; the importance of DA is the framework around the decision-making process. Finally, other decision theories can be complementary and incorporate into the DA process, depending on the business decision; for example, scenarios, which involve competitor's potential responses. For multi-attribute utility choices, Decision Analysis can leverage Multi-Criteria Decision Analysis (MCDA) methods, and choose the most appropriate methodology (or combination) based on the decision to be made and the difficulty in developing utility functions. MCDA is a discipline that encompasses mathematics, management, informatics, psychology, social science and economics; similar to DA is evolving and becoming more specialized depending on the type of utility to measure and the environment in which this takes place, as well as the kind of decision to be made. An analogy can be made that MCDA is to Programming as Programming Languages are to MCDA methods, i.e., MAUT, AHT, etc. Which method to use depends on the decision type, the environment, and skill level of the resources, the size of the portfolio, etc.

2.4.2 Bayesian Analysis and Networks

A core mathematical foundation for QPMI and DA is Bayesian Analysis. As opposed to the point estimators (means, variances) used by frequentist-classical statistics, Bayesian Analysis is concerned with generating the posterior distribution of the unknown parameters given the subjective data (expert opinion), the evidence, and a prior density for these parameters. As such, Bayesian Probability provides a much more complete picture of the uncertainty in the estimation of the unknown parameters, especially after the confounding effects of nuisance parameters are removed. Bayesian Analysis lends itself to analyzing uncertainty in cases where information is limited, arriving at different intervals, and when an experiment cannot be conducted even more than one time to utilize Frequentist Statistics. Furthermore, Bayesian Analysis allows hierarchical modeling of uncertainty stochastic models. Bayes Networks further extends Bayes Analysis by incorporating network diagrams with logical and probabilistic branching, consider mutually exclusive risks, conditional branching, sequential or parallel sub-models in a stochastic model affecting the potential value creation, cancellation risk, etc.

At the root of Bayesian Analysis and Bayesian Networks, it is Bayes' Theorem. The theorem defines a rule for refining a hypothesis by factoring in additional evidence and background information, resulting in an updated probability distribution (The Posterior Distribution) representing the probability that a hypothesis is true, given the known information (The evidence). The hypothesis can be updated, as new evidence is available.

The ability to solve and use Bayesian systems has dramatically improved over the past 15 years, with breakthrough algorithms and Markov Chain Monte Carlo solutions to solve calculations involving complicated determinations of posterior joint probability distributions and Bayesian Networks to model multilevel domain scenarios with probabilistic networks. The following industries employ Bayesian Methods: Pharmaceutical, Computer Science, Biology, Geophysics, Security, Decision Analysis, Game Theory, Disease Diagnosis, Military, etc. The most famous documented usage of Bayesian methods is by Alan Turing to decode the German Enigma cipher; the encryption method employed by Germany during World War II. Equally valuable on saving lives was the use of Bayes Theorem to find and destroy Germany's U-boats, which were devastating allied naval forces in 1941.

2.4.3 Stochastic Processes, Monte Carlo Analysis, and Markov Chains

These mathematical algorithms and methods are the means by which complex scenarios are modeled and simulated to forecast behavior. Monte Carlo simulation is one of the primary ways to forecast and analyzed initiatives; the modeling consists of simulating the execution of a project network (including risks as probabilistic tasks with varying degree of impact) hundreds of thousands of times, deriving a Probability Density Distribution (PDF) and Cumulative Distribution Function (CDF). Similarly, Stochastic Processes can be designed to simulate the value side of an initiative to understand and forecast probabilistically what "value" might be created. The latter is critical for prioritizing initiatives in terms of value/cost ratio; both quantities are random variables, using averages in this determination, it is most certainly a flaw in strategy planning.

2.4.4 Entropy

One has only to express verbally the word "entropy" and faces will turn to either confusion or complete misunderstanding as to what the term actually means. The intent in this monograph is not to provide a detailed review and history of entropy in all its incarnations, but to establish the concept in the present time as it is a direct measurement of uncertainty. Entropy is similar to the concept of variance, yet, it is a concept mathematically derived and arrived at from different domains and independently through time and different needs. But, like most concepts in mathematics that at first do not portrait obvious roots or wider applicability one will be mistaken. The different incarnations that entropy has taken in mathematical formalism, equations, at first look, appear as coincidence, but upon further abstraction and discovery, the beauty is found in a generic abstract concept. An analogy familiar to most will be Einstein's General Theory of Relativity; a theory that encompasses and extends Newtown's Laws of Gravitation, another it is Non-Linear Geometry extension of Euclid's geometry and further abstractions in the 20th century.

The last major wave of utilization and derivation of the entropy concept occurred in the field of Information Theory, by Claude E. Shannon in 1948. Shannon's research focus was in communication, studying the quantification, storage, and communication of information; his focus was to find the limits in the movement of information across channels. At first sight, his work does not seem at all relevant to the problem of inference, but one would be erroneous. Shannon understood that the communication of information was subject to uncertainty; he deduced different communication channels might provide different randomness and the question Shannon pondered over was which is one is better. What is the optimum communication of information given randomness? Thus, his motive was to derive mathematically the optimum amount of knowledge, information in his wording, associated with a particular random variable. Others in the physical science and engineering had derived similar formulas for entropy, but no from mathematical axioms. In creating the field of Information Theory, Shannon started the process of abstracting the concept of entropy outside of Statistical Mechanics and Thermodynamics. For a complete history and specifics on the different forms that the entropy concept took in history until arriving in its current form and areas of present research, refer to Caticha [96].

Shannon's axioms and conditions were sufficiently constraining to derive a unique value for the optimum amount of information that can be expected by a random variable. Due to the almost exact similarity to the equations derived by Rudolf Clausius for Thermo-Dynamical Entropy and Willard Gibbs in Statistical Mechanics, and Boltzmann's definition of entropy as a measured by the number of micro and macro states of a system in thermodynamic equilibrium; Shannon chose the name entropy too and symbolized it by the letter "S." But, it was not Shannon who realized that it could not just be a coincidence that his results were the same as Clausius and Gibbs. It was Leon Brillouin and E.T. Jaynes that identified the significance of the similarities. The crucial contribution of Jaynes was the acuteness that Shannon's derivation was not confined to the movement of digital bits – information – in channels; there is nothing in Shannon's axioms and derivation coupled in any way with the specifics of communication, his findings were generic and unique. Shannon's mathematics can be utilized to any problem subject to randomness in Probability Theory; Shannon's results apply to the inference that includes

Laplace's principle of insufficient reason as a special case, which will be important when eliciting subjective probabilities and information is limited and provided by different type of constraints.

There are several entropy related concepts that are utilized by QPMI:

1. Shannon's Entropy
   - To measure the Entropy for discrete random variables.
2. Differential Entropy
   - To measure the entropy for continuous random variables.
3. Maximum Entropy
   - For selecting a prior distribution when limited information is available, in the forms of constraints.

2.4.5 Deming's Theory of Profound Knowledge - Process Variation & Statistical Process Control

Understanding of variation is one of the fundamental core principles of Deming's Theory of Profound Knowledge. In particular, this sub-set of his theory involves understanding and managing variation in processes, which are not homogeneous, i.e. processes or systems that cannot be modeled and analyzed employing any mathematical probabilistic distribution. Deming's mathematical framework is based on Statistical Process Control (SPC), which was created by Walter Shewhart and it is widely utilized in managing and optimizing processes. SPC was tested and proven during the reconstruction of the Japanese economy after World War II, which fully applied Deming's methods; SPC is a primary enabler of Lean and other continuous improvement methodologies. A mistaken belief frequently encountered regarding SPC, it is that is only applicable to the manufacturing industry and that it assumes all processes are Gaussian. Neither one of these statements are correct; the underlying mathematics are derived empirically (considering 100s of different probability distributions with all types of Kurtosis and Skewness) and designed to address non-homogeneous data. SPC is a core part of the framework in various continuous improvement methodologies, including Six Sigma and Lean Six Sigma; the concepts of process variation are relevant to all knowledge-work as explained next.

Understanding process variation and SPC is crucial for QPMI, Program and Project Management, and DA. The fundamental questions for any process are: 1) is the process under statistical control? 2) Is the output generated by the process meeting the expectations the process was designed to create? What can you predict if anything from the process data collected? These are key insights that one must understand for processes, in order to manage, improve, and forecast on them. Without this understanding, changes and inferences make to and from a process are nothing but random events and speculations targeted to an issue that may or may not exist and forecasts pie in the sky. No forecasting is valid for any process unless it is in a state of statistical control.

Consider the following scenario of an executing IT initiative, an initiative whose probability of success to meet a pre-defined schedule is tracked weekly (could be any time frequency). The following data points have been collected so far by using the same analysis for each measurement, the numbers derived from each period are 80%, 75%, 83%, 68%, 72%, 81%, 52%, 66%. What is the *Voice of The Process* communicating to you (the voice is the data collected trying to speak to you, in Deming's and Shewhart interpretation)? If you are responsible for this initiative should you act? Can you forecast the future outcome of this initiative? Understanding process variation is the realm of Statistical Process Control; analysis of the collected data provides insight into the state of a process and its performing capability, the trend and behavior of a process over time, and the ability to forecast outcomes. One final point worth re-stating, a process that is statistically unstable cannot be predicted with any degree of accuracy, non-linear forces are at work that need resolving.

2.4.5.1 Theory of Process Variation

Per Dr. Deming, ***"life is variation. Variation there will always be, between people, in service, in product."***
What is the variation trying to tell us about a process, and about the people that work in it?

Types of Variation

There are two kinds of variations in all processes and systems per Dr. Deming and Walter Shewhart and eloquently summarized by Dr. Donald Wheeler as follows – reference[47]:

1. **Special Cause:**
    a. A group of data contains a dominant cause-and-effect relationship; this dominant uncontrolled cause will haunt the process, creating exceptional variation, excess costs, and general grief.
    b. The dominant but uncontrolled causes were called "*Assignable Causes*" by Shewhart and "*Special Causes*" by Deming.
2. **Common Cause:**
    a. Uncontrollable causes. This type of variation was called "*Common Causes*" by Deming and "*Change Causes*" By Shewhart.
    b. Deming estimated 97% of all variations is of this type. Therefore, requiring no intervention, unless the system as a whole is targeted for improvement.

You cannot optimize any system when some of the dominant cause-and-effect relationships remain unidentified. It is only as you listen to and learn from the process data, that you can develop a complete understanding of your process. Using this knowledge, you can operate your process more profitably. Without this understanding, you will continue to operate at the mercy of the Assignable/Special Causes.

In order to differentiate between Common and Special Causes and continuously monitor for changes in a process, a technique must do the following:

1. Allow you to learn from your process data.
2. Warn you when your process changes.
3. Help you to identify the causes of those changes.
4. Enable you to operate your process predictably and on target.

Mistakes Managing Variation

There are two mistakes frequently made in attempts to improve results, both costly – from Reference[47]:

1. **Mistake 1.**
    a. To react to an outcome as if it came from a "*Special Cause*", when actually it came from "*Common Causes*" of variation.
2. **Mistake 2.**
    a. To treat an outcome as if it came from "*Common Causes*" of variation, when actually it came from a "*Special Cause*".

The Process States

Stable and Unstable-States – per Reference[47]

1. A process may be in statistical control; it may not be.
2. In the state of statistical control, the variation to expect in the future is predictable. Cost, performance, quality, and quantity, are predictable. "Shewhart" call this *The Stable State*.
3. If the process is not stable, then it is unstable. Its performance is not predictable.
4. All processes are subject to entropy; they will suffer from atrophy over time unless they are pro-actively managed for signs of decay.

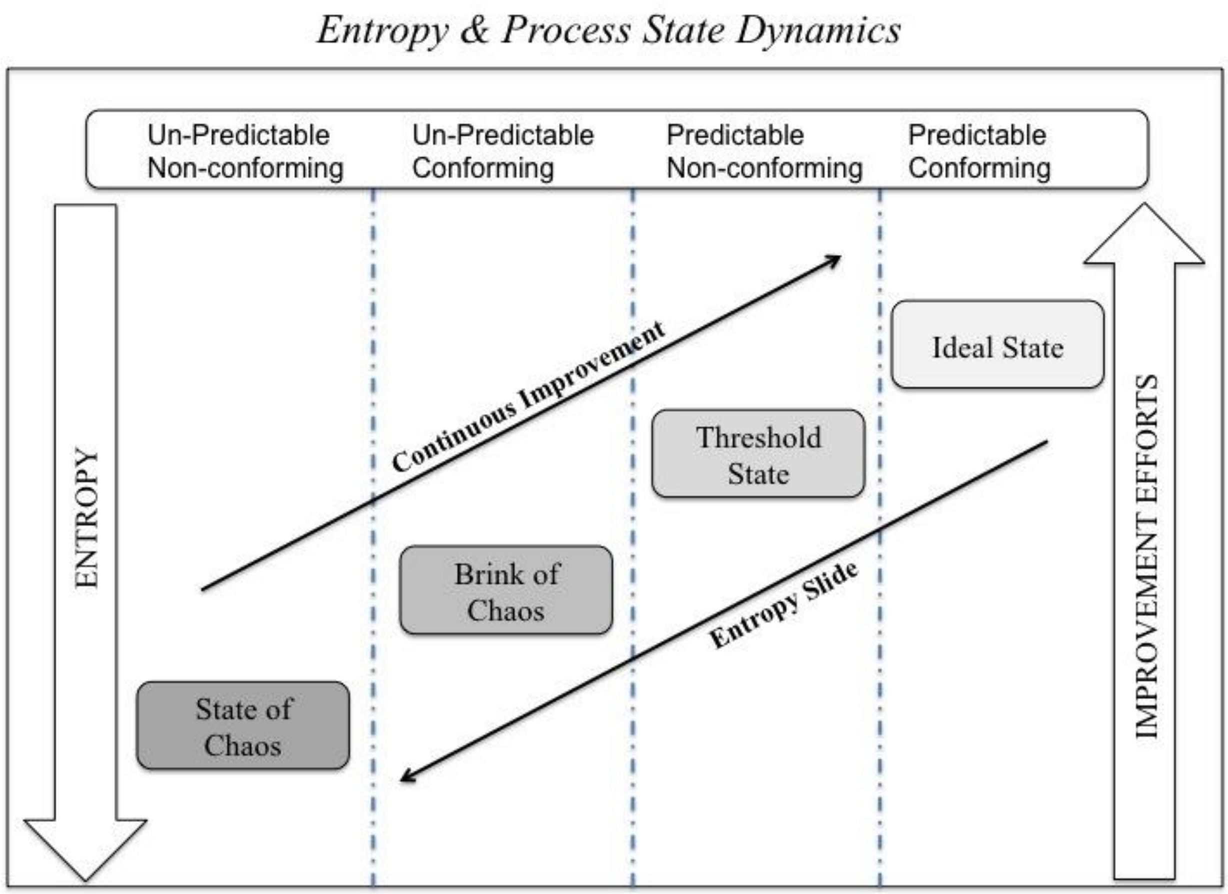

Figure 2.7, Entropy & Process State Dynamics

2.4.6 Prospect Theory & Judgment under Uncertainty, Heuristics and Biases

To effectively deal with uncertainty, we must become comfortable with using limited information and with subjective assessments about the future. An expert provides his or her beliefs in the form of a quantitative answer for both values and probabilities, to ensure that the expert is providing an unbiased perspective and assessment; one must search for and counteract Cognitive and Motivational Biases. Additionally, it is known that estimation of software development projects (tasks, user-stories, work-items, etc.), the range representing the 10^{th} and 90^{th} percentile tends to be narrowed upon comparison against historical results; one or more than two cognitive biases are at played. The expert elicitor, encoding the designated domain experts for their estimates, must be keenly aware of the biases and employ tactics detailed in References [77, 78]

Per Tversky and Kahneman Nobel-winning work, bias is defined as "a conscious or subconscious discrepancy between the expert's response and an accurate description of his or her underlying knowledge." They identified two types of biases in their research, which are used in our ability to predict and assign probabilities to events (past, present or future):

1. **Motivational Bias**
   Biases caused by personal interests, which can conflict with proper evaluation of the initiative, such as:
   – Won't have a job if this initiative fails, if it is not approved.
   – I can do anything given enough time and money.

– I am an expert; why should I be uncertain?

2. **Cognitive Bias**

   Biases introduced by the way the expert processes information are harder to detect and correct, due to the following reasons:

   1. Anchoring
      - It is a bias towards a starting value and occurs when you let the expert give you their best estimate first. A well-known instance of this bias is *Parkinson's Law*; the work expands so to fill the available time for its completion.
   2. Availability
      - It is a bias that causes overestimation of the probability of occurrence due to recent events.
   3. Coherence
      - It is a bias that produces a higher probability of occurrence than is warranted due to an easy and plausible scenario.
   4. Overconfidence
      - It is a bias that usually results when an expert believes he or she knows everything about the subject in question.
   5. Representativeness
      - It is a bias that results from an expert stereotyping events that are similar.
   6. Sampling
      - It is a result of having too much faith in certain information. Usually, it is information, which has either been refined or comes from a noted authority such as the U.S. Government. While the information may be accurate and of good quality, the expert may be placing too much faith in the information without knowing all the assumptions and manipulations that is present in the data. In particular troublesome, it is relying on statistical studies and analysis claiming cause and effect relationships and consider for gone assertions of truth due to meeting a statistical "p-value". Recent analyses of studies published in many scientific journals have been found to be non-reproducible and subject to "p-hacking" (Selectively ignoring or including outlier data points , or aggregating to meet the magical "p-value" cut off).

3.0 Introduction to Quantitative Portfolio Management of Initiatives (QPMI)

The aim of QPMI is the delineation of a formal approach that an organization can use to orchestrate, evaluate, and select initiatives with the ultimate goal of maximizing the odds of value creation, subject to the organization's degree of risk tolerance and constraints. Subsequently, QPMI prescribes the set of tools, methodologies, mathematics, statistics, and economic theories to apply for solving the stated goals. A portfolio methodology must account for multiple constraints and factors in the optimum selection of initiatives; the most common include:

- The probabilistic risk-reward of each initiative.
- The available portfolio funding.
- The likelihood of an initiative's development duration and cost.
- The cancelation-failure plausibility.
- The dependencies and correlation effects among initiatives.
- The multi-attribute and multi-period utility characteristic of the candidate portfolio initiatives.
- Uncertainty from either aleatory, epistemic and ontological events to the utility, duration, and cost for initiatives.
- The risk tolerance for the organization or direct management of the portfolio.
- Resource availability, required skills, and loading factor.
- Diversification strategy

The portfolio selection planning process is orchestrated by a group of decision makers within an organization, led by a Portfolio Manager. An analytical evaluation of all previously listed criteria for each initiative and the portfolio as a whole is necessary to assay the optimum way to invest the organization's capital and human resources to maximize the odds of meeting a company' strategic directive and corresponding goals for the portfolio.

Portfolio Management does not involve executing the projects and programs making up initiatives, but it does involve recommending which ones to execute, pause or cancel based on Financial Portfolio Management Theory and Deming's Theory of Profound Knowledge (section 2.4.5). QPMI can be considered as a client-partner of Water Fall, Agile, Critical Chain Project Management (CCPM) and any other methodology utilized for managing software, infrastructure, business processes, services, and construction initiatives. However, unlike all of the previous methodologies (except for CCPM), it requires and expects quantitative analysis and updates. Additionally, QPMI requires accounting for Common and Special Causes of Variation during the execution process of initiatives. In the latter variation, a complete understanding of the internal and external execution risks; information which needs to be delivered periodically to the Portfolio Manager for analysis. The risk information communicated must include a subjective assessment of the probability of risks occurring, and if they do, the probabilistic impact to the duration, cost, and potential cancellation overall rate of an initiative.

Other groups that may interface with QPMI are Product Management and Business Development (Strategy), depending on the organization. Product Management and Business Development roles are usually intermingled; these groups are charged with business strategy development and corresponding roadmap; QPMI is a partner to both groups. Product and Business Development focus on high-level business planning and direction. QPMI role is providing analytical recommendations to a Portfolio Management Board on the selection and prioritization of initiatives, and the performance of the ones under execution. Considering facts as known at the time of evaluation, and the uncertainty underlying each initiative as discussed in section 2.3.3.1.

One of the roles of a QPMI governance board is evaluating each potential initiative first to determine if it supports the goals and objectives of the business and secondly if it meets the portfolio defined parameters for initial consideration. Initiatives that fail the selected filtering criteria might be eliminated from the selection and analysis process. The QPMI board also examines the interconnections and contingencies among initiatives. These relationships can affect the ranking, prioritization, funding and selection of initiatives within the portfolio; the degree of correlation between initiatives for either the executing phase or value-creation, it is a critical component of the overall variance-volatility in portfolio optimization. Finally, the QPMI board monitors initiatives that are in motion. Poorly performing initiatives may affect others within the portfolio, and potentially could be candidates for replacement with other initiatives in the pipeline per the portfolio optimization and prioritization criteria; consistent monitoring of portfolio initiatives, using quantitative methods to quantify uncertainty in an on-going basis is required.

3.1 Portfolio Analysis and Management, an Introduction

A Portfolio is a collection of initiatives that compete for the same resources. Resources are anything that must be allocated to an initiative for it to be completed; these include money, time, people, raw materials or equipment. Human resources are typically not fungible. The skill set of each resource should also be considered when allocating resources based on the needs of the initiatives.

Portfolio management and analysis is imperative when one or more of the resources are limited, and not all the initiatives can be funded; every company's reality. A Portfolio Manager and supporting Portfolio Governance Board (PGB) are faced with a series of decisions concerning which initiatives should be funded and which ones need to be placed on hold. Furthermore, depending on the PGB bylaws, portfolio management provides strategic leadership and direction to the business regarding the executing initiatives, based on probabilistic status performance, execution and value potential, and the degree of alignment with the strategic and governing parameters for the portfolio.

3.1.1 QPMI and Program-Project Management – Similarities and Differences

QPMI considers the triple constraint concept in standard Project Management Methodology from PMBOK to be just the tip of the iceberg. One of the objectives of QPMI is maximizing value delivery, and projects and programs are the means to achieve it. Initiatives must be assessed from various facets, so one makes the right investment that generates maximum value for the organization in accordance with a pre-defined organizational strategy.
Iceberg areas:

- Additional or new revenue streams
- Customer Satisfaction
- Organization Goals
- Shareholder Value
- Product Quality
- Efficiency Gains
- Employee Value
- Other types of values: Security, Compliance, Availability, Safety, Operational Business Continuity, etc.

A Program (PMBOK guidelines, no Agile) is managed for the triple constraint: Scope, Cost, and Time, and consequently a program or project might be completed successfully regarding schedule, cost and time, but no be successful at all. Why?

1. It delivered an inferior product.
2. The customer is unsatisfied.
3. A superior product with quality might also not be necessary truly successful if:
    a. No customer value was created in the long run. After all, it is the prospect of the value to be delivered to the company and consumers, the reason why investments are undertaken. The end-customers cannot be more apathetic to the triple concern criteria, and consequently, the same should be for the business and stockholders. Unsatisfied customers are and should be the primordial drive, as they are the source of the revenue and wellbeing of companies.
    b. Even if 1, 2, and 3a are achieved it might not be a truly successful project, why?
        i. It may have damaged the environment.

ii. Made fatal safety mistakes.
iii. Destroyed employee morale.
iv. Violated laws and ethics.
v. Put the organization at a much higher level of risk regarding security, compliance, etc.

A Portfolio is managed by a different set of criteria: Goals, Initiatives, Constraints, Risk Tolerance and Uncertainty; QPMI must consider and manage to all of these criteria. The “question” that any portfolio management system must answer is: What are the set of initiatives that the company should execute to meet the goals and business strategy given the organization’s constraints (resources, budget, legal, compliance, prospective value, etc.), risk tolerance, and known uncertainty within each initiative, and the covariance relationship among initiatives?

An enterprise-wide QPMI process provides an overarching strategy to manage the various icebergs in an organization, by assessing, monitoring, and managing initiative’s icebergs collectively, in the right direction for the distant future. Failure to do so means letting randomness dictate the future and operating in a sub-optimal manner; value-creation throughput would not be driven analytically and quantitatively as it is with Finance Portfolios.

3.1.2 QPMI and Financial Portfolio Management – Similarities and Differences

Financial and Initiative portfolios contain assets that belong to distinct categories and subcategories. In fact, multiple levels of categories may exist. Financial assets are instruments such as individual stocks and bonds, whereas a portfolio of initiatives is comprised up of projects, business processes, programs, and services among other vehicles to create and deliver value.

Initiatives within a portfolio can be assigned to multiple categories for aiding on portfolio management. The following is list of standard categories and sub-categories that can be employed:

- Size (small, medium, large)
- Type (development, infrastructure, service, business process, etc.)
- Development Time (short, medium, long)
- Qualitative Risk for duration, cost, and prospective value (low, moderate, high)
- Quantitative Risk for the duration, cost, and potential value.
- Qualitative Cancelation-Failure Rate (low, medium, high).
- Quantitative Cancelation-Failure Rate.
- The probability of Success for meeting cost, duration, and prospective value projections.
- Expected Value for cost, duration, and value projections.
- Strategic Alignment

Portfolio Objective (Financial and QPMI):

- The objective of investing in assets of either portfolio is value creation and maximizing the return for the owners consistent with the organization’s investment strategy. This must be done in the context of risk for long-term sustainable performance.

Portfolio Value:

- Financial Portfolio:
  It is equivalent to the value of the assets it contains at any given time in the financial markets.
- Initiative Portfolio:
  Far harder to estimate for the following reasons:
  - The value generated by an initiative may not be of a financial form and not objectively quantifiable.
  - Most often the value is realized over an extended period of time rather than immediately after an initiative completes.

- The expected value that will be generated is uncertain, requiring a quantitative framework and systematic and repetitive management methodology to ascertain the range of possibilities and their corresponding likelihood.

Portfolio Risk:

- Financial Portfolio:
    - Primarily market driven while market risk is only a part of an initiatives portfolio's overall risk.
    - Liquidity
    - Interest Rates
    - Government Regulations

- Initiative Portfolio:
    - Nonmarket risks:
        - Technology
        - Feasibility
        - Resource skill set
        - Resource availability
        - Production capability
        - Management effectiveness
        - External dependencies (Contractual, Compliance, Legal, Environmental, etc.)
    - Market and Policy risks:
        - Time Window
        - Competition
        - Government regulations
        - Obsolesces due to new market trends, behavior

Many Financial Portfolio Principles are directly applicable to Initiative Portfolios. Harry Markowitz laid the foundation for today's financial portfolio management in 1959. The principles and the details of the concepts and applicability are discussed in section 2.3.3.1.

Principles applicable:

- A portfolio should be constructed in accordance with the overall investment strategy and goals of the investing organization.
- A portfolio has two macro sources of risks:
    1. Individual risk related to a given asset on the portfolio itself.
    2. Correlation Risk, how a given asset is related to the others and the corresponding impact on the overall portfolio.
- Diversification minimizes portfolio risks.
    - Avoid overdependence on one asset or a category of assets.
- Investment portfolios are subject to Aleatory, Epistemic and Ontological Uncertainties.
    - Research and methods applicable to quantifying uncertainty due to future events.
- The portfolio should be selected in accordance with the efficient frontier concept.
    - The portfolio should be selected as to maximize the prospective expected value for a given degree of risk tolerance.
    - There is a spectrum of optimum portfolios creating the highest values for different levels of risks.

Themes Applicable to Initiative Portfolios:

- Alignment
- Value Creation
- Portfolio Balance
- Long-Term Performance

- Efficient Frontier
- Risk Management

A primary objective of any portfolio management system is determining the level of investment versus risks adjusted value, how much money to invest? Is there a combination of initiatives that provides optimum value for a given level of investment? Is there an optimum point of investment, such that increase investment does not provide additional risk-return value? The rate at which the additional investment begins to return less incremental value from an optimum point, even so, the value still increases. A marginal investment increment does not create as much value as a lower investment point.

3.1.3 QPMI and The System

QPMI's key objective, like Financial Portfolios, is maximizing value for an organization with the resources available and tolerance for risk. Consequently, it is necessary to understand the aim of the organization it supports, the business strategy in the short-and-long term, and the vision for the organization; what is it that the organization values? This continuous self-retrospect is a process influenced by the realities of external market forces demanding never-ending adaptation from any organization.

Deming's principles bestowed through his Theory of Profound Knowledge are directly applicable to managing initiatives in a portfolio. Deming's principles serve as the foundation for directing and aiming the focus of QPMI in an organization, as well as cooperating supporting groups, i.e., Business Strategy and Product Management.

What Business Are We in?

- The organization must continuously ask and considered:
    - What Product or Service would help our customers more?
    - We must think about the future.
    - What products and services will be making five years from now? Ten years from now?

Appreciation for the System

- A system is a network of interdependent components that work together to try to accomplish the aim of the system.
- A system must have aim, without an aim, there is no system, and any portfolio management methodology is directionless and non-effective.
- Interdependence.
    - The greater the independence between components, the greater the need for communication and cooperation between them, and the greater will be the need for overall management.
- Efforts of various divisions in a company, each given a job, are not additive. Their efforts are interdependent.
- Obligation of a component.
    - It is to contribute its best to the system, not to maximize its own production, profit, or sales, nor any other competitive measure.
    - Some components may operate at a loss to themselves, occasionally necessary for optimizing the whole system.
- A Win-Win Philosophy as Basis for Negotiation.
    - Best for everyone concerned should be the basis for negotiation between people, between divisions, between union and management, between companies, between components, etc.

Boundary of a System

- It may be drawn around a single company, or around an industry, or as in Japan, the whole country.
- The bigger be the coverage, the bigger be the possible benefits, but the harder to manage.

The following is an adaptation of Deming's famous System View of the world, modified to include the role of Portfolio Management, Product and Strategy Management in an organization.

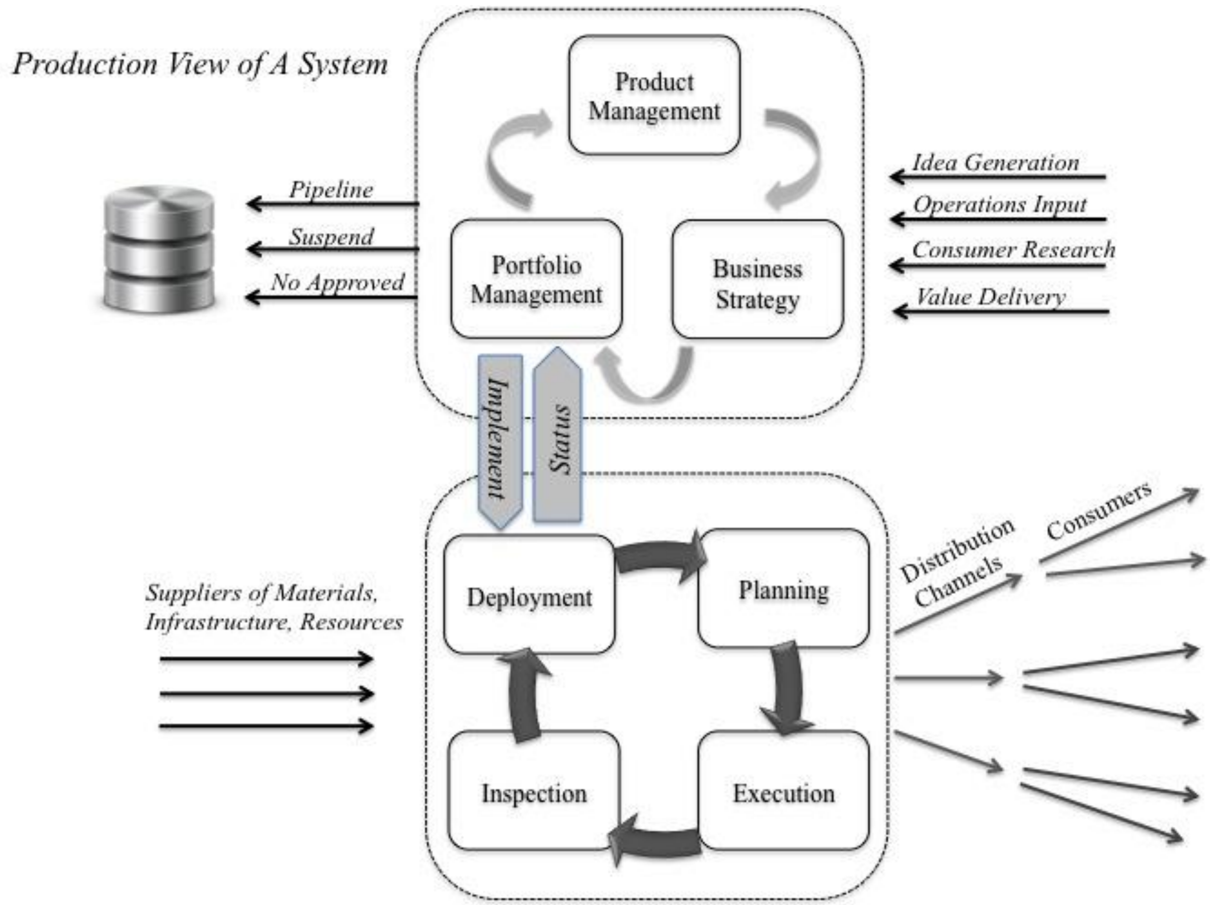

Figure 3.1, Production View of a System

3.1.4 QPMI and Organization Strategy

"Deciding what not to do is as important as deciding what to do -- Steve Jobs."

A company may choose to manage each strategy with a single portfolio or multiple ones; there is not correct answer; the choice predicates on the complexity and similarities of the organization strategies. The challenge all businesses confront is almost always deciding what initiatives to do, what will generate the greatest value for the short and long term, a difficult on-going decision for all organizations, and eloquently expressed by Steve Jobs. Appreciation for the limitations and constraints of the resources, the essential need to focus on the few and not the many, it is a demanding responsibility for most organizations; departments within companies are aware, but few embraced and operated accounting for them. Most often than no, there exists the mistaken belief that more can be done, if workers just work harder, more tasks can be multi-tasked, without losing focus and affecting the overall performance and throughput of value creation. Even worst, the selection criteria for initiatives are based on the instinct of a few without an independent analysis to serve as a foundation of the decision-making progress. Consider, the counter-analogy in the Financial Portfolio environment, selection of assets without detailed qualitative and quantitative due diligence, and just on "gut-feeling." A counter-argument can be made that certain inviduals have the wisdom and the ability to see the future; therefore able to chose the best path forward. Indeed, Steve Jobs himself was such a visionary, and for investing Warren Buffet, but they are statistical outliers and no the norm, and in the case of Buffet his financial investing principles are rooted on analysis. For indepth discussion on the subject of randomness, see reference [85], Fooled by Randomness.

Initiative Portfolios are the means by which organizations can maximize the odds of generating the most value according to a company's strategy. The role of Portfolio Managers of Initiatives is similar to Financial Portfolio Managers, the application of Modern Portfolio Theory or derived methodology to select what is the optimum combination of assets for investment in the portfolio. The list of candidate initiatives to include for consideration in a portfolio is the role of Business Development or Product Management or both, in most organizations. Portfolio managers must closely collaborate with Business Development, Product Management, and Program Management in the planning, evaluation, and selection of initiatives; serving as an impartial functioning unit, whose aim is analytical and quantitative ranking of the optimum set of initiatives to execute based on the portfolio parameters. This latter goal is meant to provide unbiased recommendations based solely on a well-defined set of policies, procedures, and analytical techniques. All of which needs to be applied in a repeatable and consistent manner and within a well-established and accepted corporate framework to manage a portfolio of initiatives, similarly as it is conducted at Financial Institutions.

3.1.4.1 Business Strategy and Relationship to Initiatives, Programs, Products, and Projects

Diagram 3.2 denotes a way to conceive the hierarchical structure for an organization strategy, from strategy, as the root node, to projects, the leaves in the tree. The tree is a map displaying the relationship between strategies, goals, initiatives, programs, products, services, business processes, and respective projects. For clarity, only one of the branches in the strategy map is expanded.

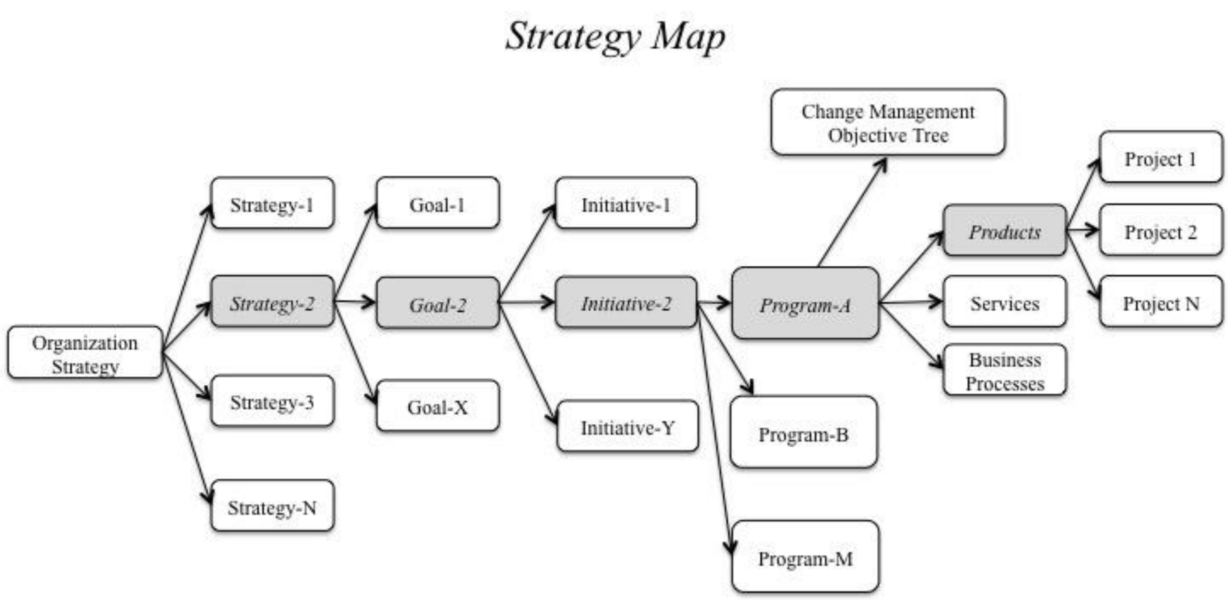

Figure 3.2, Strategy Map

3.1.4.2 Sample Strategy Tree

The sample depicted in Figures 3.3, 3.4, and 3.5 corresponds to a hypothetical eCommerce organization in the business of selling tickets to consumers. In this exemplification, the business executives and product team identified several strategies; the "*Increase Online Sales*" is selected as a key strategy to pursue by the organization to increase sales and customer satisfaction. Other strategies for the same division are also depicted, but not expanded. The question for the sample company is what strategy to execute? How to best allocate resources? What goals and initiatives within a strategy provide the best value in the short-term and long-term? What are the potential value benefits to be gained and the underlying uncertainties for each?

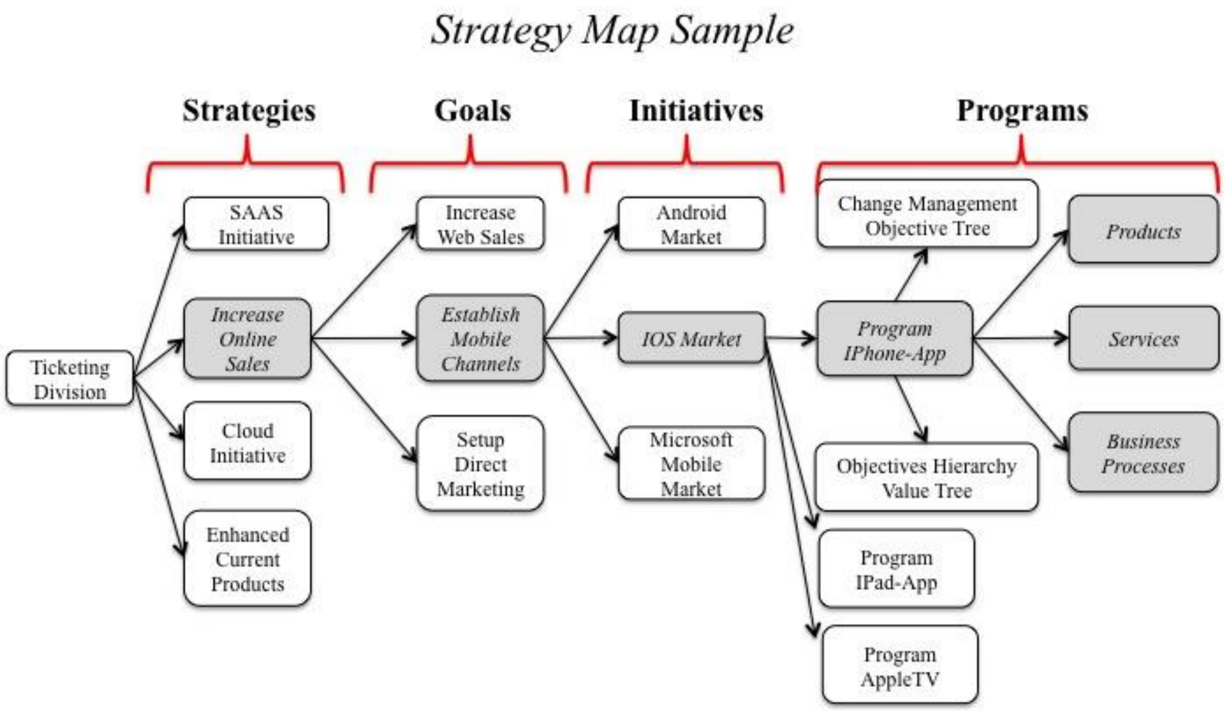

Figure 3.3, Strategy Map Sample – Part 1/3

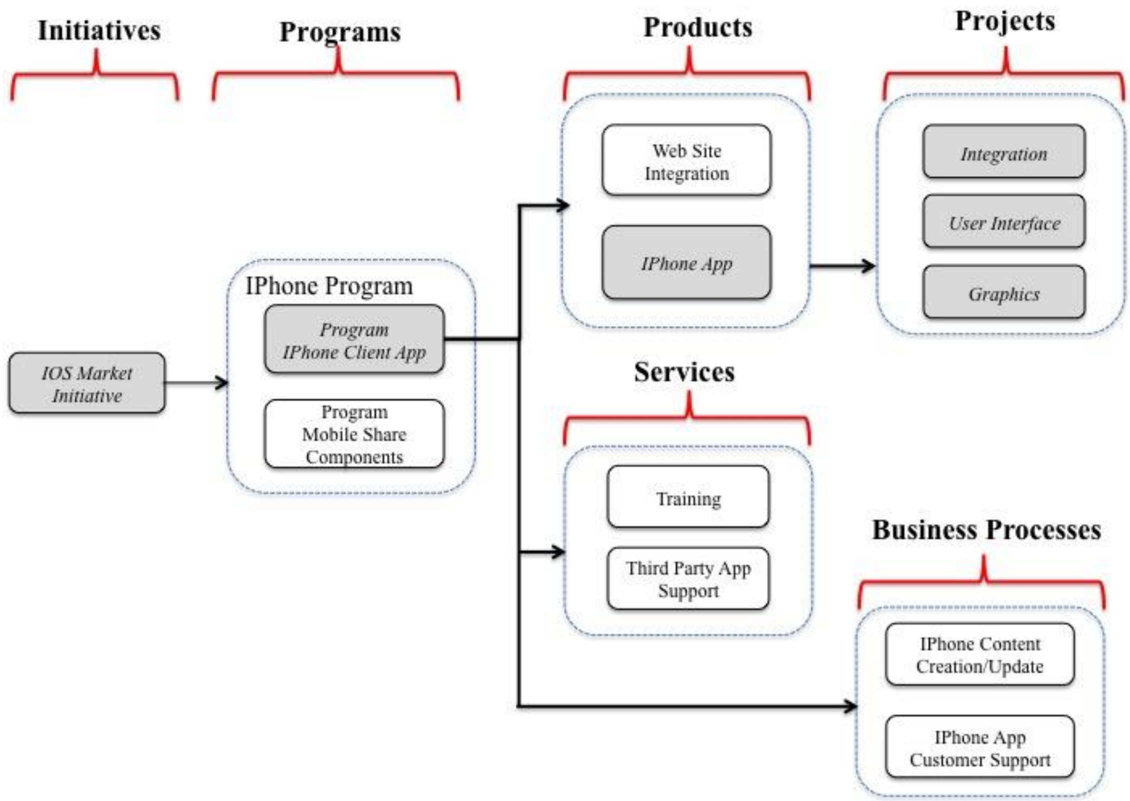

Figure 3.4, Strategy Map Sample – Part 2/3

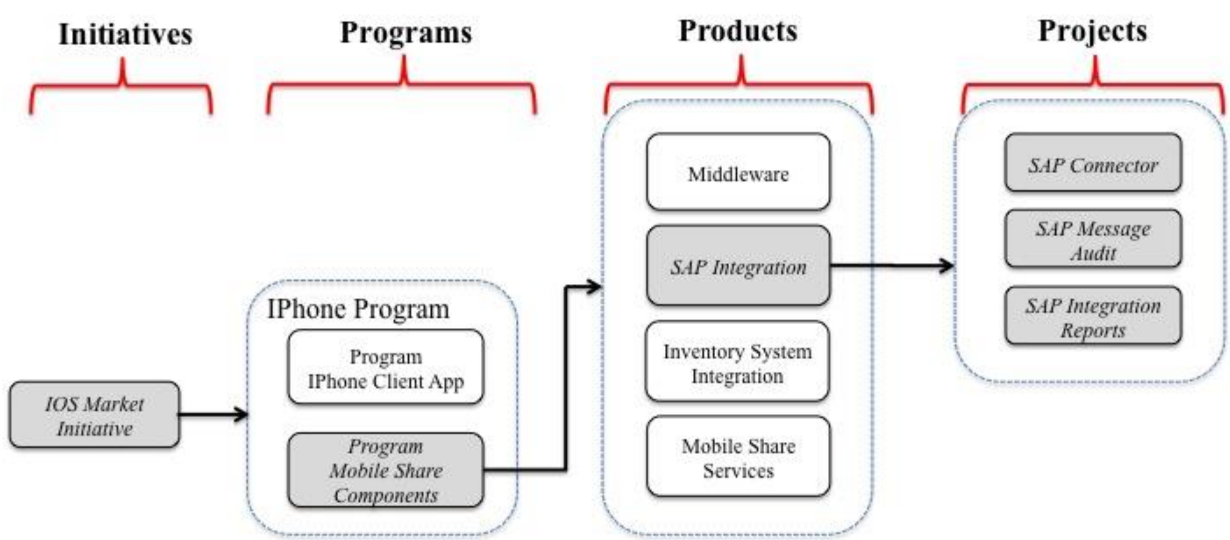

Figure 3.5, Strategy Map Sample – Part 3/3

3.1.5 QPMI and Change Management

"It is not necessary to change; survival is not mandatory. -- W. Edwards Deming"

Change Management is the process of introducing change in an organization. The change can be a new or revised company goal. The greater the complexity and magnitude of change, the greater the necessity for analysis and utilization of a standard change management methodology, such as The Theory of Constraints – Thinking

Process, Deming's Theory of Knowledge, or John Kotter's Business Change Management methodology. The bigger and more impactful the change, the greater consideration for employing Change Management; methodologies just listed are complementary and can be leveraged together. A change might involve software and infrastructure development, creation or modification of business processes, policies, and procedures among other elements. Finally, and most importantly, it is the formulation of a conceptual assessment of the plausible consequences of the change (positive and negative), a cause and effect diagram, depicting the different potential outcomes and their probabilistic impact for occurring.

Per the sample strategy map laid out defined in Figures 3.3 to 3.5, the strategy goal is the establishment of the IOS Market's sales channel. The IPhone Client App Program consists of several components, albeit the app, the most obvious one. Further review of the sample strategy map, lists another required program for the IOS Market Initiative to be realized (the list is not meant to be exhaustive just illustrative) and an emblematical list of subcomponents. Potential negative impacts of the change, unless considered, could be level of customer and third-party add support, internal competing marketing strategies for different sale channels, etc.

Embarking on a Change Management assessment for large and complex initiatives is a prudent and pro-active risk reduction technique. The cause-effect diagram analysis aims to identify the possibility of different effects from a change, negative and positive, and consequently the necessary pre-emptive remediation actions that ought to be considered for planning, and the consequences and impacts if the potential consequences are not addressed pro-actively. Conducting a detailed Change Management process on a costly, large and complex initiative starts the process of risk identification, both material or human, ultimately, it is this understanding and preparation for unplanned happy path effects that are the primary target of consideration. In addition, assisting with the delineation of the sequences of steps in the introduction of a major change. The relation of Change Management with QPMI is due to the latter need to measure and quantify the probability of success in delivering initiatives for a given risk level, and the likelihood of the value creation. The Portfolio Manager together with the Product and Program Management teams need to ensure a detailed assessment identifying all programs and their components (services, products, business processes, projects) are mapped and planned. The inclusion of expected and unexpected effects and preemptive remediation steps, if it is deemed necessary to minimize risk and potential large negative impacts. Additionaly, even if remediation steps are not implemented, understanding of the probability of the risk occurance and degree of impact; it is necessary for comprehensive evaluation of the variance statistic for an initiative's cost, duration and expected value to be generated (The variance statistic is required by PMT for analysis).

QPMI, similarly to PMT, requires the quantitative evaluation of uncertainty associated with initiatives and its programs. Fix date estimates, such as the famous "Red", "Green", and "Yellow" status and corresponding trending arrows are of no used to portfolio analysis; they do not provide a quantitative measure of uncertainty and inclusion of the Common and Special Cause variation that all initiatives are subject to. What does a yellow or red status mean to the possibility of meeting a date? How can anyone determine how fast a project is improving or deteriorating by visualization of the angle of a trending arrow in a status report? Ignoring issues and risks identified in Change and Risk Management is unwise and fooling oneself with a false sense of security, assuming there is not potential negative impact from a major change or that risks are just events that might occur but no worth including in planning and evaluation of an initiative.

Leveraging a standard change management methodology should be considered for highly complex goals with a potentially high risk of business disruption, cost, human safety, and any other factor deem critical by the PMB. Incremental updates to a particular product line with already established processes, products, and services may require just minor updates of well-known behaving components, and a full change management process will be an overkill, similarly, for short and low-cost projects. All of the factors highlighted, plus any others unique to each organization must be designed and incorporated during the construction phase of the portfolio framework. Business rules, utility functions, methodologies, metrics, filtering criteria, etc. must be defined ahead of time to remove subjectivity and apply based on criteria agreed by the Portfolio Management Board.

The following sections provide a high-level summary of Deming's and TOC Change Management System Methodology. For a comprehensive description of the methodologies and appreciation of the impact they have on a system undergoing change, see references [35-38, 44, 45, 51, 68].

Deming's Profound Knowledge

"Profound knowledge must come from outside the system, and by invitation. – W. Edwards Deming"

Systems and Profound Knowledge:

– According to Deming, profound knowledge comes from:
    - An understanding of the Theory of Knowledge.
    - Knowledge of Variation.
    - An understanding of psychology.
    - Appreciation for Systems.

Theory of Constraints

The theory rests on the admittedly somewhat rash assumption that managers and organizations know what their real purpose is, what goal they are trying to achieve. Unfortunately, this is not always the case. No manager can hope to succeed without knowing four things:

1. What the ultimate goal is.
2. What the critical success factors are in reaching that goal.
3. Where he or she currently stands in relation to that goal.
4. The magnitude and direction of the change needed to move from the status quo to where he or she wants to be (the goal).

Change and the TOC

Deming talked about "transformation", which is another way of saying, "change." The TOC is essentially about change. Applying the TOC principles and tools answers the four fundamental questions about change that every manager needs to know, they are:

- What is the desired standard of performance?
- What must be changed?
- What to change to?
- How is the change best accomplished?

The above are system-level questions, no process-level, even so, they have an impact on individual processes, but they are designed to focus efforts on system improvement. Processes are important, but organizations ultimately succeed or fail as complete systems. The distinction between systems and process is critical, from System Theory; the whole is not equal to the sum of the parts.

TOC Principles

1. **Systems as Chains**
    - If systems function as chains, the weakest links can be found and strengthen.
2. **Local vs. System Optima**
    - Because of the interdependence of systems components and the effects of entropy, the optimum performance of the entire system is not equivalent to the sum of all the component optima.
3. **Cause and Effect**
    - All systems operate in an environment of cause and effect. Something causes something else to happen.
4. **Undesirable Effects and Critical Root Causes**
    - Nearly all of what we see in our systems that we do not like are not problems, but indicators. They are the resultant effects of underlying causes.
    - Treating an undesirable effect alone is like putting a bandage on an infected wound: It does nothing about the underlying infection, so its remedial benefit is only temporary.
5. **Solution Deterioration**

- An optimal solution deteriorates over time as the system's environment changes, the natural process of everything in the universe (Entropy).
- "*Yesterday's solutions become today's historical curiosity*" -- Goldratt
- A process of Continuous Improvement is essential for updating and maintaining the efficiency (and effectiveness) of a solution.
  - Inertia is the worst enemy of a process of ongoing improvement.

6. **Physical vs. Policy Constraints**
   - Most of the constraints we face in our systems originate from policies – how we deliberately choose to operate – not physical things.
   - Physical constraints are relatively easy to identify and break.
   - Policy constraints are much harder to correct, but they normally result in a much larger degree of system improvement that does the elimination of a physical constraint.
7. **Ideas are Not Solutions**
   - The best ideas in the world never realize their potential unless they are implemented.
   - Most great ideas fail in the implementation stage.

The diagram below, Figure 3.6, provides a high-level view of the TOC Thinking Process methodology and its principal logical components. It is a robust methodology developed by Elijah Goldratt to manage change and conduct continuous process improvement.

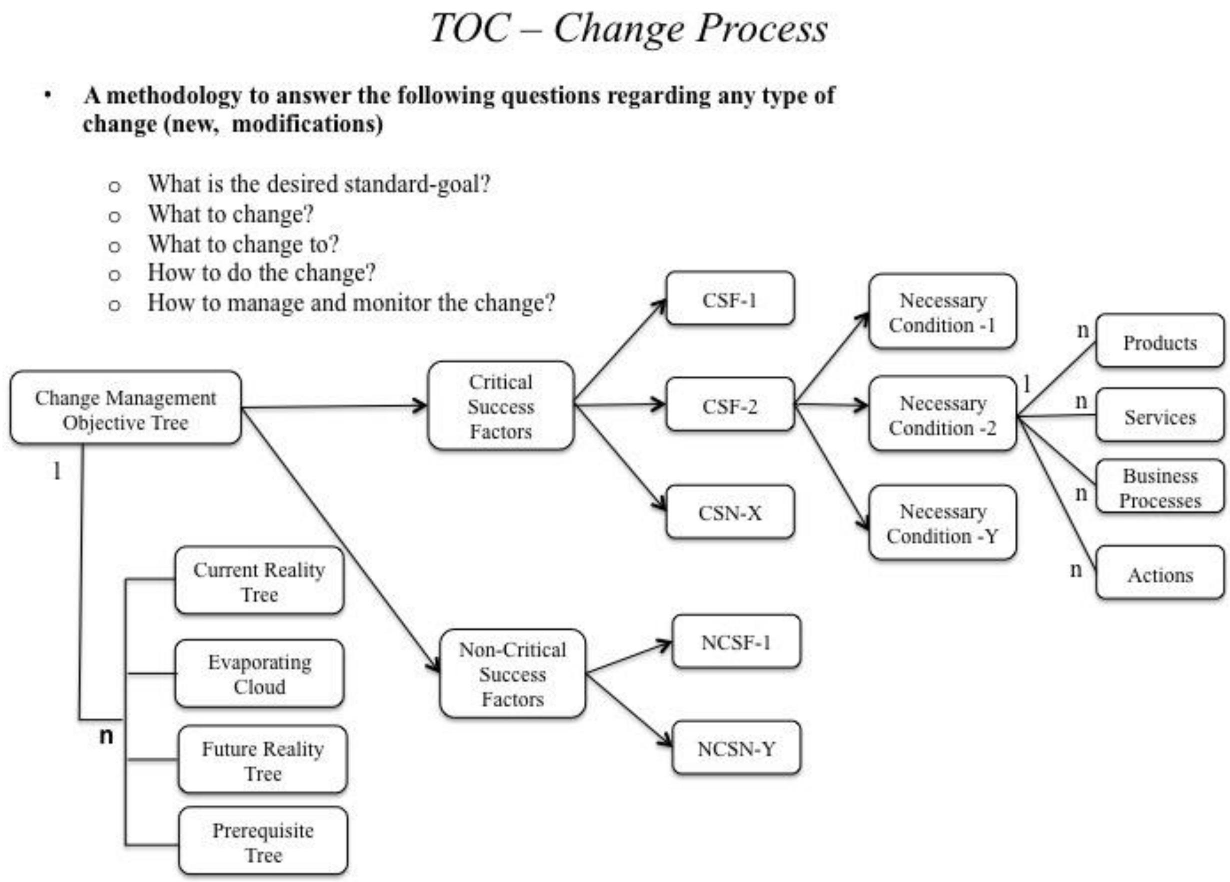

Figure 3.6, Theory of Constraints (TOC) – Change Process

3.1.6 QPMI and The System's Constraints

All systems and process have an underlying constraint, which limits the capacity of the overall system. System constraint theory is fully defined by the Theory of Constraints (Eliyahu Goldratt – *The Goal*). This methodology was discussed in the previous section, and it applies to System Optimization as well as Change Management. A Portfolio Management of Initiatives should understand what the system's constraint is in an organization; the ability to maximize the value creation throughput of the portfolio relies on this factor. Other areas of critical importance regarding System's Constraints are the risks associated with dependencies among initiatives and teams. Per Deming's Theory, system optimization can only be achieved for the entire system, no by optimizing individual components; this is very evident in IT organizations, where a few critical teams tend to be the limited constraint to getting work done. Therefore, understanding the capacity of the constraint, subordinating and optimizing the constraint, it is critical for value optimization at the macro level, the rate of completing initiatives.

A portfolio management system must understand the capacity of the constraint and schedule work according to this capacity. Additionally, through a process of continuous improvement, explore and evaluate ways to elevate this limiting capacity, until the targeted constraint it is no longer the system's constraint, but another one is. At this point, the process of continuous improvement is shifted to the next constraint, forever in an infinite loop.

Readers no familiar with System's Constraint Theory are encouraged to get acquainted with Deming and Goldratt's profound work.

3.1.7 QPMI and Prospective Value

Prospective Value is defined as the forecasted value to be created upon completion of an initiative. A forecast is mathematically represented as a random variable considering the uncertainty of future events. In Bayesian terms, this is the Prior Value, reflecting the probabilistic estimate, based on the data and subjective knowledge of an initiative.

An initiative's value may consists of tangible and non-tangible benefits manifesting in the short, medium and long-term horizon after completion. Forecasting an initiatives' Prospective Value requires utilization of stochastic models – Bayesian Analysis and employment of economic utility. Bayesian Analysis is used to design stochastic model(s) for estimating the value of all tangible and un-tangible benefits defined per the Portfolio Governance, i.e. corresponding to the portfolio's Objective Hierarchy. Second, economic utility and Multi-Criteria-Decision-Analysis (MCDA) methodology are employed to map tangible and non-tangible values in an Objective Hierarchy to utility; there are several MCDA methodologies which can be utilized for various kind of decision-making. Which particular MCDA methodolgy is selected depends on the complexity and the number of initiatives needed to be ranked (References [18,19]).

Funding, planning, and execution of an initiative does not create value, even completion of an initiative does not necessarily mean value has been created. All value is prospective until it is realized, and this occurs overtime after an initiative completes. Evaluation and comparison of different initiatives requires a methodology to compare the prospective utility of one initiative versus another (if using MAUT derived methods), inclusive of tangible and non-tangible benefits, uncertainty, cost, and risk.

Distinct MCDA methodologies have been developed over the past 50 years; their aim and goals are varied but can be categorized into two types. First, MCDA methods derived upon the economic concept of utility for ranking initiatives with multiple attributes. Secondly, MCDA methods such as MACBETH, AHP, ANP, ELECTRE and its derivatives, methods that provide ranking and sorting techniques without the need for utility, but rely on techniques based on pair-wise comparisons of all choices in a set. The latter set of MCDA methods is of limited value to portfolio analysis, without an estimation of the expected utility and underlying variance, one cannot utilize Harry Markowitz's Portfolio Management theory. Therefore, determination of the set of optimum portfolios, using the axiomatic principle of mean-variance in Markowitz's theory, it is impossible. Pair-wise ranking methods are not without merit; they can be used to derive an independent ranking to validate the one arrived at with MAUT based methods. Most commonly employed utility-based methods are Multi-Attribute Utility Theory (MAUT), ProMAA, FuzzyMAUT, etc. The choice of methodology is dependent on the organization, skill level of personnel, the portfolio size, complexity of the objective hierarchy, etc. The method selected should be defined prior to conducting the valuation analysis for any initiative; otherwise comparing values across initiatives might be subject to bias. Prospective Value is uncertain; this uncertainty must be encoded probabilistically (Bayesian stochastic models) and normalized utilizing Decision Analysis and an MCDA method(s).

Finally, the portfolio decision-making process should consider the applicability of Prospective Theory, and corresponding framing questions to evaluate each initiative; the questions prompt the decision-maker to focus on the cognitive aspect of the decision making and consider scenarios no address by standard enonomic utility theory, for example, the ability to withstand worst case scenarios (References [82,90,91]).

The following two figures, 3.7 and 3.8, illustrate the concepts in MAUT and its derivatives, the first figure it is a tree view of an Objective Hierarchy for decisions or initiatives with multiple attributes (Reference [7]). The second figure provides an example.

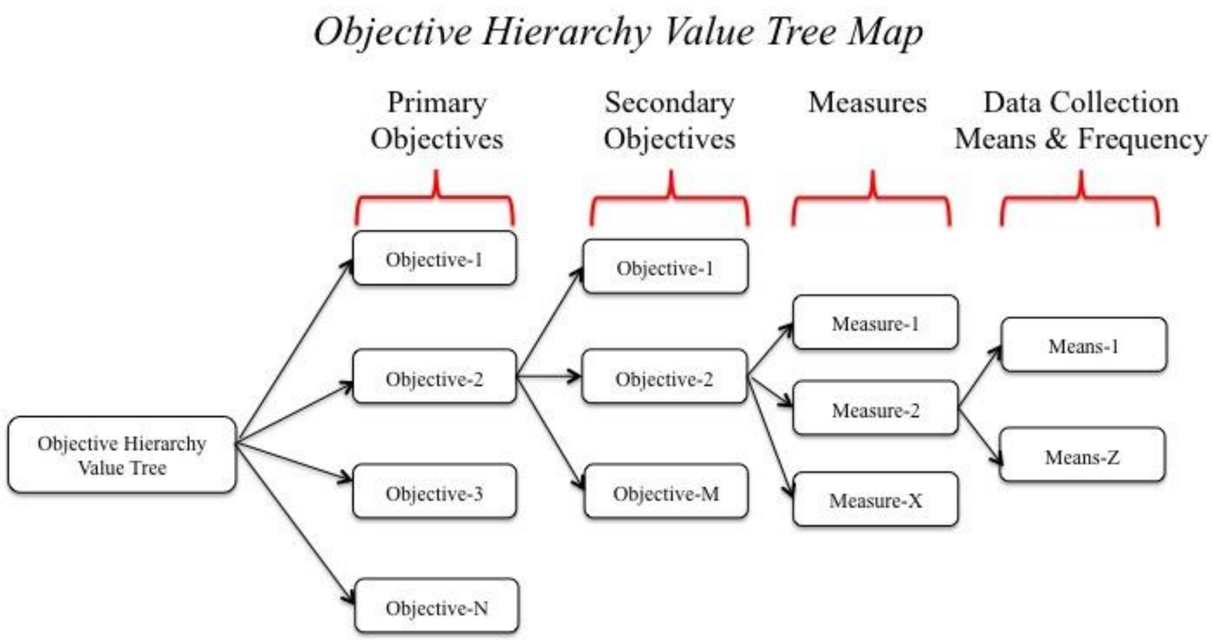

Figure 3.7, Objective Hierarchy Value Tree

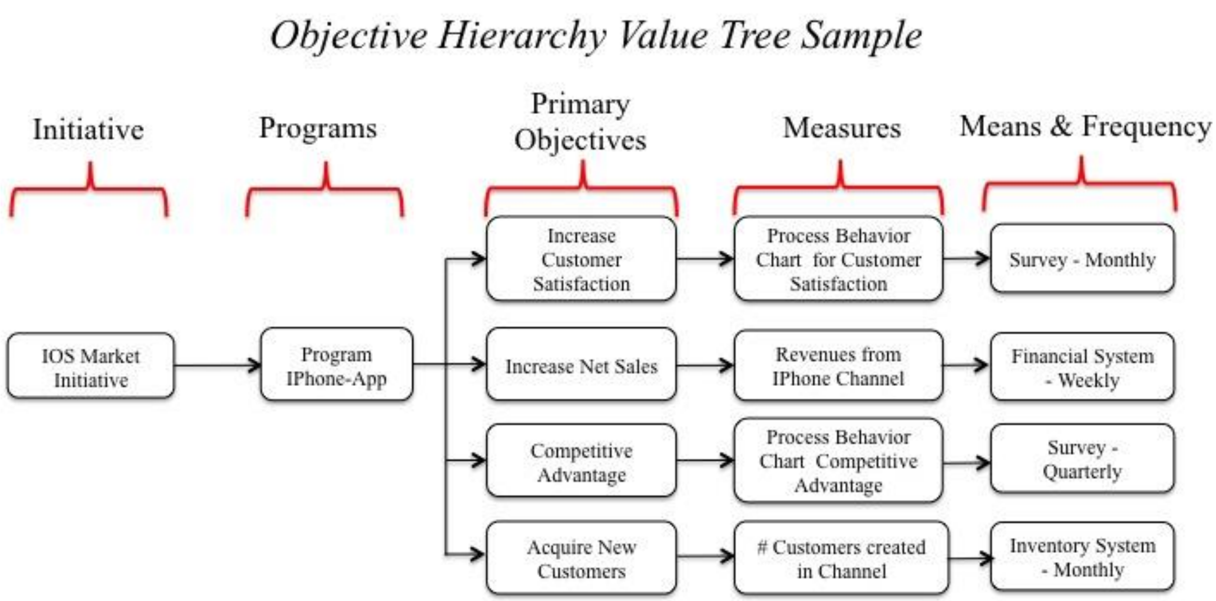

Figure 3.8, Objective Hierarchy Value Tree Sample

3.1.8 QPMI and Realized Value

Realized Value is the value created following the completion of an initiative; statistically, this type of value corresponds to the Bayesian Posterior Value. The difference between Realized Value and Prospective Value is that the latter one is forecasted while the former is a combination of forecasts and evidence – collected data denoting the creation or lack-there-of the expected value. Prospective Value forecasts are updated as data is collected to reflect our best knowledge of the present. QPMI is concerned with the ongoing monitoring and measuring of a portfolio's value. Measuring the value generated by a portfolio, within a time period, requires all initiatives to have a data-gathering plan; and a consistent process to collect and quantify value earned after an initiative’s completion. The value may increase or decrease based on the quantification of benefits, becoming less uncertain as evidence of their occurrence is manifested and measured.

An initiative may require many components (Products, Services, Business Processes, etc.), as illustrated in the sample strategy map (Figures 3.3, 3.4, 3.5). The assessment for measuring the value created by an initiative requires the creation of an Objective Hierarchy Map for an initiative(Figure 3.7). The map must include a list of the measurable parameters to be collected for each objective, the means, and frequency of the collection, and the period the attribute should be collected (References [7, 8, 18, 19]).

The value created up to any point in time can be calculated by measuring the benefits realized. Subsequently, the forecasted Prospective Value updated with the collected data. The realized benefits can correspond to one or many attributes which can be measured periodically; for instance, the attributes for expected sales, the number of users, efficiencies, etc. Influence Diagrams or Bayesian Networks can be modeled to determine the up to date actual realized and updated forecasted value or utility for any initiative; as evidence is measured, the probabilistic value is updated. A simpler approach consists of only calculating an initiative’s utility based on the data collected up to a point in time. However, if there is a need to perform what-if scenarios, trend analysis of the utility as a time-series, forecasts per region, or draw other insights from the data collected or yet to be collected, it is not possible. Consider the previously discussed sample, a company with a strategy to increase online sales; the primary means to achieve the goal identified as entrance in the IOS Market. One of the initiative's parameter may be the revenue attributed to the IOS Market by channel. It is common that a new Website or App is deployed first to a market, then to another market, region by region during a time period. Therefore, revenue projections for the whole initiative cannot be measured and estimated just by including one region; however, with a Bayesian Network stochastic model, a probabilistic estimate can be attained to better assess the future value, combining subjective data and evidence - measured data, as it is collected. This type of analysis provides greater insight to the organization for how value is being created or not, how it is trending, and avoids waiting until all regions and data points are collected to evaluate performance.

The value realized by an initiative after delivery could be positive or negative, increasing or decreasing, depending on the impact to the customer and the levels of benefits reached. The importance of value analysis is to gain an understanding of the degree of success or failure for a completed initiative, “completed” defined as delivered to end users. The results should be used to modify a product roadmap, decision analysis criteria, and other processes employed during the planning, evaluation, and prioritization of initiatives, so that continuously improvement becomes part of the Strategy Planning, Portfolio, Product and Program Management processes.

There are several options to measure value for an initiative, from simple periodic data collections via surveys to periodic data collection of parameters from enterprise resource applications (Financial, HR, Databases, etc.). Benefits realization is a continuous process of envisioning results, implementing, checking intermediate results and dynamically adjusting the path leading from investments to business results. Benefits realization is a process that can and must be managed, just like any other business process.

The realization of benefits is a process of measuring and tracking a set of attributes; these parameters can be leveraged to monitor if the desired outcomes are indeed present upon completion of an initiative. Outcomes are typically not something you can measure by themselves – Only when we see the benefits; we can say an outcome is achieved.

The events, event definition, and delivery value chain for completed initiatives is:

1. **Sequence of events**
   - Project Completion → Outputs → Benefits → Outcomes
2. **Project Completion**
   - Project officially completed, but not necessarily deliver to end-users.
3. **Project Prospect Outputs**
   - Prospect, since completion of a project, does not indicate the desired output was achieved, until evidence it is collected to confirm it.

- Outputs are the components of the project delivered and available for use to end-users.

4. **Benefits**
   - Outputs have benefits; benefits are the tangible results that can be measured. For instance:
     a. Sales
     b. Customer Satisfaction
     c. Efficiency for task durations
     d. Cost savings
     e. Increase safety
     f. Compliance
   - Some of the benefits above have qualitative aspects, which need to be translated into a quantitative measurement, the details of this process are unique to the MCDA methodology selected to evaluate an initiative's objective hierarchy and corresponding utility.
5. **Outcomes**
   - It is the realization of the objectives of an initiative.

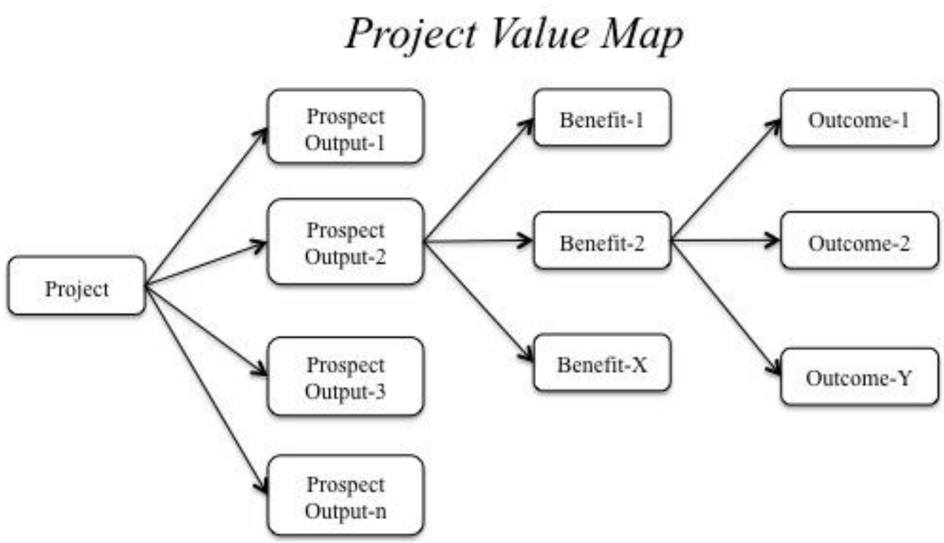

Figure 3.9, Project Value Map

3.1.8.1 Realize Benefits

What are benefits? In John Thorp's "*The Information Paradox"* book, he defined and detailed the concept of benefits, as follows: (Reference [10]):

"*The benefits mindset is based on the following premises:*

- *Benefits do not just happen. They do not just automatically appear when a new technology is delivered. A benefits stream flows and evolves over time as people learn to use it.*
- *Benefits rarely happen according to plan. A forecast of benefits to support the business case for investment is just an early estimate. It is unlikely to turn out as expected, much like corporate earnings forecasts. You have to keep checking, just as you would with a financial investment that fluctuates in value on the securities market.*"

Benefit Types

There are four different kinds of benefits, one of them is tangible and intangible, and another is efficiency and effectiveness.

1. ***Tangible benefits*** are those that can be measured by a parameter, quantitative and often of financial nature.

2. ***Intangible benefits*** are those that can only be judged subjectively and tend to employ qualitative measures. However, indirect parameters can be used to formulate a quantitative value. These are often called 'soft' benefits and examples of such benefits would be an improved ability to make decisions or improved satisfaction. Employment of economic Utility Theory and Multi-Criteria Decision Analysis provides one option to convert qualitative intangible benefits to a quantitative value. Consider the following example, measuring the success or failure of safety promised by a pipe gas initiative whose objective is minimized gas leaks. There can be multiple parameters that can be collected and measured, such as the number of reported leaks, the performance of parameters installed to detect leaks (have they statistically improved?), etc. Multiple parameters can be combined and weighted to derive an overall utility score for the degree of safety achieved, and equating that score to qualitative score based on the results.
3. ***Efficiency benefits*** are those benefits that seek to reduce costs of performing a particular process by utilizing IT or any technological product. For example, saving money by reducing the workforce, speeding up transactions or shortening product cycles. These kinds of benefits do not change the nature of the objectives that the changes were devised to fulfill.
4. ***Effectiveness benefits*** are ways of doing different things to achieve the required results better, for example providing a strategic competitive advantage or developing new products or services that are designed to increase profit.

Each of these benefits types can be classified as an outcome for delivering an initiative. These outcomes and expected benefits should be formulated ahead of time to avoid introducing biases in the evaluation of the value delivery, adjusting formulation to give more weight to benefits collected. Any changes to the valuation approach after initiative completion should be carefully tracked and approved by the PMB with substantiating reasons free of biases. There are valid reasons to do this; one example is when new benefits are realized that were not envisioned during the planning.

Benefits Statements

Some examples of qualifiers that are often used in Benefits statements include:

• Increase • Enhance • Strengthen • Improve • Reduce • Lower • Eliminate • Maximize • Minimize • Avoid

Such benefits that are quantitative and financial are often termed 'hard.' An example of such benefit would be the cost savings caused by introducing an IT process to automate the creation of virtual environments. There are also benefits that are easy to measure, but hard to directly associate with any financial benefit. For example: The speed to deploy changes to production, the degree of test automation and coverage (these last two can be quantified in terms of financial value, provided additional data is collected), etc.

If benefits are what we receive, then value is what we perceive. Benefits should be thought of as the operationalization of the value construct. Summarizing what has been described so far with an example:

- Outputs:
    - ➢ Integrated Sales, Inventory, and Delivery Management Systems
- Benefits:
    - ➢ Reduced costs for system support.
    - ➢ Reduced time between sale and customer delivery.
    - ➢ Improved inventory management.
    - ➢ Accurate sales orders
  - – All of the above benefits can be quantified, and whenever possible the data distribution of the change should be measured, and no the fatal mistake to focus on the "average." The change can be just randomness due to aleatory uncertainty.
  - – What one should strive to understand is, if the trend, the statistical process for each of the above has narrower or shifted operating limits compared to the pre-delivery state.
    - ➢ Was the changed reflected in the graphs of the data collected?
    - ➢ Have the limits of the process narrowed or increased, if so by how much?
- Outcomes:

- Increased efficiency in order processing.
- Orders are accurately and efficiently delivered.

- Perceived customer-client Value:
  - I get what I ordered when I expect to get it.

If not all of the previously identified benefits and outcomes are achieved, there might still be value delivered, though it may be less that what was expected. Alternatively, perhaps, there were areas where the value was worsened or unaffected by the outputs.

3.1.9 QPMI and Utilization of Uncertain Information and Judgment

"To be absolutely certain about something, one must know everything or nothing about it – Olin Miller."
"If we begin with certainties, we shall end in doubts; but if we begin with doubts, and are patient in them, we shall end in certainties – Sir Francis Bacon."

Effectively dealing with uncertainty requires becoming comfortable with the use of limited information. Including: Subjective assessments of the future, probabilities, stochastic models, and first and for most accepting the human inherent limitation to predict the future with certainty and no full ourselves; and always have present George Box's famous insight *"all models are wrong, but some are useful*". A way to interpret this famous quote is that even so models could be wrong, they can be useful. How useful? The answer varies based on the data, domain, and model; the insight of this profound quote is never to forget our limitations and to realize models are not necessarily exact-predictive theories of the future.

Another aspect of managing uncertainty in decision-making, it is the judgment to understand what information is necessary to make a decision and what information would change our decision. The wisdom to comprehend the impact of risks and issues and the criticality to include their probabilistic effects in an initiative's forecast; the awareness, to the extent that is known (black-swans can not be anticipated by definition) of epistemic and ontological uncertainties for an initiative, and their potential consequences. Finally, the knowledge to be keenly aware of cognitive and motivational biases with expert's elicitation of estimates.

Forecasting the future involves using limited information to identify and select the best course of action. Avoid falling into "Analysis Paralysis" -- It is easy to fall into the trap of asking for more and more information. Almost all decisions, especially those involving the future, are based on limited information; we must understand both the variability and the reliability of our information. The data ranges should be reliable rather than accurate. Accuracy implies precision, and precision is difficult and impossible in the case of complex initiatives subject to realistic planning and no infinite long schedules.

Gathering Information, it is essential for an assessment of what is relevant and needed to solve or estimate a problem. Furthermore, selection of which experts should be assessed, should not be confined to internal experts only, many times the best experts may be external. Once the experts have been identified, they must be unbiased and calibrated and then assessed. Uncovering biases is not a trivial process, but it must be done to ensure the most reliable information is gathered. The subject of which experts, how many and type of experts, the protocol to access the experts is an on-going area of research that has been active for the past 50 years or so. Refer to *Advances in Decision Analysis* by Edwards Ward (Reference[27]) and *Uncertain Judgments: Eliciting Expert's Probabilities* (Reference[77]) for a present comprehensive review of expert's elicitation research and techniques.

3.1.10 QPMI and Forecast Verification

QPMI relies heavily on Bayesian Methods, utilizing available limited historical data, expert's judgments, and applicable future forecasts of relevant parameters to design stochastic models. Subjective Probability Theory –

i.e. Bayesian Analysis Theory, states, *"You have your beliefs about events. If these events taken together obey certain consistency conditions, and if, when new evidence appears, you update these beliefs using Bayes Theorem, then we can treat degrees of belief about various combinations of events as probabilities"*. Even though this sounds too magical and Objective Probabilities and Orthodox Statistics appear to be more scientific and valid, this is indeed not the case, since all models and the decision of what statistical method to use is subjective. When face with a complex stochastic modeling problem, frequentist statisticians tend to no agree but in the most simple scenarios on how to model and what methods to apply. Statistics is more similar to engineering than mathematics, there are many ways to build a bridge, no one right away, but some ways are better than others. Regardless, objective probabilities are not an option, as initiative selection and decision-making, it is not a control experiment that can be repeated in random trials (a requirement for the utilization of Frequentist Statistics), the challenged facing QPMI does not lend and it is feasible with the Frequentist approach.

Frequentist Probabilities are a specialized case of Bayesian probabilities, E.T. Jaynes derived the axioms of probability from "Plausible Reasoning" logic (see Reference [14]); the same axioms that Kolmogorov stated in 1933 to first establish Probability Theory as a full branch of mathematics. The main difference in their work, it is that Kolmogorov just stated the axioms; Jaynes derived the axioms from an extension of Aristotelian logic, providing absolute firm ground and based understanding on the logic for choosing the axioms, and consequently a deeper understanding of how Probability Theory can be interpreted. Prior to Kolmogorov's work, Probability Theory was though of ad hoc methods for calculating odds in gambling games, starting with Kolmogorov and culminating with Jayne's work, Probability Theory has been firmly established on par with other Mathematical Theorems. Many others (Harold Jeffreys, Jimmie Savage, etc.) contributed during this period establishing Probability Theory, and primarily Bayesian Analysis, at the forefront in the field of statistics no longer playing second fiddle to Frequentist interpretation of Probability Theory.

The use of Bayesian Analysis does not limit analysis to only Subjective Probability, if historical data is available, the information can be leverage to the extent to which it is applicable using Empirical Bayes Methods. Bayes Theorem can be updated with any data and posteriors beliefs calculated accordingly. Regardless of the type of probability employed in analysis, the main point to be mindful of, it is that all probabilistic forecasts should be verified for accuracy. Having skin in the game is what turns wishy-washy utterances into real subjective probabilities. Failing to put money, with symmetrical levels of reward and punishment when making forecasts, means assessments failed to stand up to the most crucial requirement for predicting probabilistically, the willingness to back up predictions with actions. In whichever form these actions take form, they must have an equal amount of reward per that – anything goes – a monetary reward system is required. The website https://www.predictit.org exemplifies the Bayesian way of thinking to forecast the future. Anyone can bet on any aspect of an election, up to $850 per contract is legally permitted in the US. The Predictit Trading Market exemplifies several aspects of forecasting the future, use of Subjective Probabilities, limited historical data, constant updating of the odds as new relevant data appears, and the concept of the "Wisdom of the Crowd." The latter states that when making predictions about the future where limited data is available and uncertainty a fact, the most likely outcome is the expected value of the estimates. Predicit takes this a next step and adds the requirement of financial repercussions on all predictions.

Whenever we listen to predictions or risk assessments, we should always keep in mind how and to what extent the person issuing the forecast is rewarded for correct predictions or punished for false alarms. Predictions with no gain or pain and a "settlement date" are vacuous utterances. Focusing on the outcome of a "bet" automatically makes us nondogmatic probabilists, and allows us eclectically to embrace whatever tool we have at our disposal to arrive at the best prediction we can (i.e., at the prediction that you will find best to profit from).

Several aspects of Portfolio Management involve issuing forecasts subject to uncertainties. Assessing the performance of these forecasts requires the utilization of methods to evaluate how predictable and reliable the forecasts are. The field of Forecast Validation has been evolving for the past decades; Atmospheric Scientists have been at the leading edge of developing and utilizing scoring systems to improve the accuracy of their forecasting, a lot can be leveraged and learned from this domain. The nature of their field lends itself to constant evaluation, as weather forecasts outcomes, can be quickly observed and the predictions evaluated.

There are a variety of scoring systems; the most applicable to Portfolio Management are the Brier Score, Logarithmic Brier Score, and The Continuous Rank Probability Score (CRPSS). The most appropriate to QPMI is CRPSS since the scoring methodology is designed to validate probabilistic forecasts, see References [79,80,81].

When comparing results from a Forecast Validation analysis, the comparison must be conducted in similar domain problems. In the case of Portfolio Management, this means the scores should be compared to initiatives of similar characteristics; i.e. size, complexity, domain. Initiatives with different characteristics should not be directly compared in regard to their forecast scoring, but just juxtaposed to discern the forecasting difficulty across them. Failing to follow the comparison score guidelines will result in invalid and bias findings, with the drawn conclusions exhibiting erroneous judgment and lack of comprehension in the appreciation of uncertainty problems. The degree of difficulty of the forecasting problem, the similarity of the problem domain, needs to be similar to infer conclusions from scores. An analogy can be drawn for meteorologists issuing forecasts in different geographical regions; the scoring and skill level of forecasters in Seattle and Los Angeles must not be compared, the weather pattern differences are very distinct, with Seattle much more varied than Los Angeles.

3.1.11 QPMI System Objective

3.1.11.1 Questions to be answered by a Portfolio Management of Initiatives

1) Which initiatives to execute and their ranking?
   - What is the optimum set of initiatives to execute based on the following criteria?
     - Portfolio / Organization Strategy
     - Investment capital
     - Resources
     - Constraints (Policies, Compliance, Legal, etc.)
     - Uncertainty
       - Common and Special Cause (probabilistic)
       - Aleatory, Epistemic, Ontological
     - Value (financial and nonfinancial)
       - Probabilistic
       - Utility
       - Prospect Theory
     - Risk Tolerance
       - Business attitude towards the downside, how much risk is the business willing to take on a given initiative?
       - Risk needs to be encoded with probability.
       - Investment Philosophy:
         - High reward, high risk?
         - Medium reward, medium risk?
         - Optimization Methodology, i.e.
           i. Low risk and cost and maximum expected value (Efficiency Frontier)
           ii. High risk and uncertainty and maximum expected value.
           iii. High probabilistic chance of meeting a given value range for a particular risk profile.
     - Variance Criteria
       - Standard deviation
       - Semi-Variance
       - VAR (Value-At-Risk)

        - CVAR (Conditional VAR)
    - Investment Allocation goals
        - New products
        - Old products
        - Short vs. long term initiatives
        - Security, Compliance, New Markets, Quality, Customer Satisfaction, etc.
    - Initiative Requirements
        - Required portfolio initiatives
        - Minimum or Maximum number of portfolio initiatives
        - Binary inclusion or exclusion of a group of initiatives in a Portfolio

2) What is the prioritize list of initiatives?
    - As a result of an optimization analysis, considering the factors in question 1), the list of prioritized initiatives mapping to the Portfolio operating policies.

3) What is the business adjusted list of prioritized initiatives?
    - The business adjusted list of prioritized initiatives from 1). The PMB can override the optimum rank list derived analytically. Any manual ranking and selection should be analyzed to inform the PMB of the impact to the Portfolio, i.e. Value Creation, Portfolio Risk, Cost, etc.

4) How do the funded initiatives align with the organization strategy and objectives?
    - How many initiatives are aligned with each strategy and corresponding goals, objectives?
        - Allocation of funds per goal/strategy
    - Are there goals or strategies no funded?
    - What is the expected value for strategic alignment for each initiative?
        - Strategic alignment is a subjective weight based on the input of the PGB; it should be normalized based on business utility to compare the value of different initiatives.

5) What is the probability of success for the initiatives in the portfolio completing under current planning?
    - The joint probability distribution of delivering for all initiatives executing, as currently planned.
    - If initiatives have different importance and value contribution; which is the most common scenario and denoted by the potential utility value to be derived from an initiative. The formulation of the stochastic and financial models must account for it, and appropriate weights assign to each initiative. For example, consider a portfolio with ten initiatives, two of which are expected to contribute 80% of the expected value. If these two initiatives are lagging behind schedule, and the rest are ahead of schedule; the majority of the value expected from the portfolio most likely will not be realized (initiatives may potentially be cancel or suspended), even so, the majority of initiatives are on tracked and on budget. Therefore, one should not consider just the probabilistic chance of succeeding to individual initiatives, but also factored in the appropriate relative weight of the 'value potential'/benefit of each initiative to avoid a misleading indicator. This is similar in concept to a financial portfolio heavily weighted towards a couple of assets, if those positions are not performing; most of the portfolio is affected.
    - Another important consideration for deriving a joint probability success indicator is the relative size of each initiative. Simply doing a convolution operation without accounting for initiative size does not provide an accurate joint distribution. Similar to the previous example defined above, if a portfolio has ten initiatives, but two of them are each ten times greater than the rest; then simply joining their individual probability distributions of success yields an un-accurate assessment of reality.
    - Another consideration is normalizing initiatives based on the Expected Utility Value.
    - What it is important, it is to be mindful of what success means for the portfolio. The metric or metrics must be defined with an explicit context, and clearly, delineate all assumptions on its derivation to avoid obfuscating the actual status of the portfolio. If necessary, multiple metrics for success can be employed; it is an acceptable answer. Transparency over obscurity into a

single number should be the rule. Success, like Risk, are both one word, but their meaning and context is not directly associated with one metric; aggregation of data and parameters to derive "The metric/parameter" to map these words should be avoided.

6) Does the Portfolio planning account for Common and Special Cause Variation?
   - Does each initiative account for both kinds of variations in their planning?
   - What is the impact of known Special Cause events to each initiative to the portfolio?
   - Are deterministic estimates being used? If so, when will the Common and Special Cause variations be included in the planning?
   - What process is in place for each initiative to systematically and pro-actively manage both kinds of variations for each initiative?

7) What are the success summary statistics for all executing initiatives in the portfolio?
   - Time-Chart of initiatives versus the probability of success.
   - The mean and standard deviation for all initiatives in the portfolio for cost, schedule and value creation. Note, the same concerns as defined in question 5) apply here, one must be careful just reporting summary statistics and be aware of the caveats that may surround these numbers.

8) What is the Process Behavior Chart for each initiative [actual-completion minus baseline-prediction] duration versus time?
   - The purpose of this analysis is evaluating the delta deviation between planned versus actual duration for initiatives on an ongoing basis.
   - How sensitive is the planning process? Does it vary by area, initiative size or cost? The goal of this information gathering is to provide self-assessment and no finger pointing; the ultimate aim is to narrow the difference between planned and delivered schedule, and leverage the results for continuous process improvement.
   - This data can be subsequently used for future planning, and to learn what type of initiatives (size, complexity, domain) have the most potential for planning improvement.
   - Determine if initiative execution behavior is under statistical control.

9) What is the Process Behavior Chart for each initiative [actual minus baseline-prediction] cost versus time?
   - Similar reasoning and purpose as question 8), but for the cost parameter.

10) What is the Histogram of Reasons for Initiative Delays and their impact on schedule and cost?
   - The aim of this question is the continuous analysis and monitoring of the list of Undesirable Effects (reasons) and their frequency across initiatives to use in a process of continuous improvement.
   - This data focus on the reasons causing the most delays and then using a Continuous Improvement Process, such as the Thinking Process (TP) to identify the root-cause(s). The primary objective is to achieve statistical process control for an initiative's duration (see question 8.) and reduce the variation of the process.

11) What is the Process Behavior Chart for the Number of Cancel Initiatives versus time?
   - The purpose of this analysis is to determine the rate that initiatives are cancel.
   - The goal is to understand the rate, trending, and if it is statistically stable. Cancellation of initiatives is one of the two primary risks to new initiatives; the other, the actual delivery of the Prospective Value.
   - Cancellation rate by initiative type or other metadata is an important factor on quantifying the expected value for an initiative and consequently for conducting the portfolio analysis.

12) What is the Histogram of Reasons for Canceling Initiatives?

- The aim of this question is continuous analysis to monitor the list of Undesirable Effects (reasons) for canceling initiatives, and their frequency across all initiatives to use in a process of continuous improvement.
- Similar to question 8). This data is critical to conduct root-cause analysis and minimize cancellation of future projects, by first identifying the reasons then systematically addressing the ones contributing the most to cancellations. Upon identification of the top root-causes, the Thinking Process or other continuous improvement methodologies can be utilized to reduce the cancellation rate.
- Reducing the overall cancellation rate of initiatives is a primary target of portfolio management. The Prospective Value of each initiative is directly dependent on it, and consequently the expected value that is potentially achievable for the portfolio.

13) Is historical data regarding the performance of previous initiatives in the company, and other relevant information considered in the planning?
    - Prior history, company or industry-wide can and should be included in the planning. The rules regarding inclusion of historical data should be defined during the formation of the portfolio.
    - A sample scenario follows. If it is known that most (90%+) organization-wide SAP projects over the past five years were late in the range of 25% to 50% (duration and cost) over initial baseline estimates, this information can be and should be factored in the analysis. Regardless of the existence of historical data at the organization level, one should utilize industry-wide prior statistics for delivering to improve the forecasting, establishing a Bayesian prior and updating it based on the available data.
    - Is there historical data for the number of bugs created, feature or user-story to bug ratio, etc. within a similar domain project?
    - Do statistics for fixing different types of bugs in previous similar domain projects exist? This kind of information is very useful in improving the accuracy of forecasts, and if not available, industry-wide rates for bugs creation and bug fixing rate should be applied in the planning. These estimates can also be attained from expert elicitation familiar with the problem domain.
    - Regarding scope-creep, the following questions should be considered to improve forecasting:
        - Does historical data indicating the percent of features completed, or user-stories, or requirements versus planned items exist per initiative?
        - Is there data quantifying the amount of re-work per feature, user-story due to unclear requirements?

    The above questions aim towards quantification of new scope discovered during development and validation, scope due to misunderstandings of requirements, and scope or changes due to incomplete requirements.

14) Does the portfolio have the right risk balance per the approved operating guidelines?
    - Risk balance is defined as the probability of success as presently planned relative to the value expected to be created; “Value” itself is a probabilistic parameter.
    - The risk balance for a portfolio is probabilistic and dynamic; it will fluctuate with time. Understanding and managing that fluctuation is the domain of other questions on the list. The following are potential causes that may impact the risk versus reward balance of a portfolio:
        - The schedule and cost will vary due to Common and Special Causes.
        - Aleatory, Epistemic or Ontological uncertainty.
        - The Prospect Value will vary due to:
            - Market forces
            - NPV value projections affected by competitors, cost delays, first to market, etc.
            - Strategic alignment can vary; the PGB can change priorities based on new business realities.
        - New initiatives in the portfolio.
        - Completed initiatives.

- What are the initiatives that have the greatest impact on the overall probability of delivery for the Portfolio?
- Which initiatives have the greatest risk sorted by Prospective Value?
- Which initiatives have the greatest risk sorted by cost?

15) What is the portfolio budgeted variance from current planning (present probability of delivery) to achieve an 80 or 90 percent likelihood of success?
    - Initiatives are typically planned for an 80 to 90 percent probability success, considering all Common and Special Cause variations, as well as relevant historical data.
    - In general, it is possible that all initiatives complete on time if they only have an "average" probability of completion success. However, it is not very likely as the number of initiatives increases. First, consider a portfolio with five mutually exclusive initiatives, each with a 20% completion probability of success; the overall probability of success for all initiatives delivering on time is 0.032%. The same scenario, but with a 50% probability of success for each initiative, results in an overall probability of success of 3.125%. Same as the chance of flipping a coin heads five times in a row.
    - The purpose of this question is to determine the gap, if any, between budgeted cost from current planning and a realistic completion schedule. What should the portfolio targeted Probability of Success be? This is a decision the PMB must define during the construction phase of a portfolio.
    - The answer to this question will vary dynamically for the same reasons as explained in question 8).
    - It is also important to understand the budgeted deviation trend; this is further explained and covered in question 17).

16) Is the portfolio performance statistically stable with respect to the targeted duration schedule of its initiatives?
    - All processes have variation; each initiative and the portfolio itself are executing instances of a process. A key determination is if the portfolio and initiatives are statistically stable regarding project duration. Is the duration variation of any initiative varying in time, statistically stable? Is it out-of-control, trending to be out-of-control?
    - Knowledge-work initiatives like software development projects are empirical and no deterministic endeavors. This question aims to understand how the portfolio and its executing initiatives are operating over time. For example, for a given initiative with an 80% initial planned probability of success, is the project duration fluctuating within a statistical control range? The value of this interval is specific to each initiative; it provides an insight of what to expect or not, and the trending.
    - The portfolio is statistically stable if the combined sum of all of his parts is statistically stable. However, there is always a danger of aggregating data and missing underlying trends, thus, it is critical to conduct the analysis at the initiative level as well as the portfolio level.
    - Understanding if a portfolio is statistically stable or not is paramount to determine if the organization is operating at a sub-optimal level regarding the rate of value creation, i.e. the value throughput (the rate of normalized initiative completion). The effects of Queuing Theory and resource Multi-Tasking are non-linear undesirable-effects which might adversely affect initiative portfolios; this type of non-linear behavior can be very damaging as the potential impact is exponential delays in the lead-time to complete tasks and consequently, projects, see References [52, 53, 57, 61, 72, 74].

17) Is the portfolio performance statistically stable regarding the cost variance (planned versus actual)?
    - Similar question to 11), but for the cost parameter.
    - The cost variance needs to include the actual cost up to date, plus the forecast cost base on future planning, accounting for Common and Special Cause variation in projects.

18) Is the company spending enough on short and long-term initiatives?
   - The PGB defines the duration for short, medium and long-term initiatives.
   - This question aims to answer what percentage of executing initiatives falls in each category, and what is the funding distribution for each.

19) Are all the existing products and services supported?
   - A portfolio typically services a division or group with many products and services. This question provides visibility into the planned and existing support for assets and their fund allocation.

20) How much spending is appropriate between updating old products and developing new ones?
   - The ratio of funds allocation is decided and put into place during the portfolio framework construction phase.
   - The ratio of allocation should be revisited periodically and updated base on a company's updated strategy and goals.

21) Are company's resources operating at optimum productivity?
   - Optimum does not mean 100% resource utilization capacity. This question aims to manage the resource loading on the portfolio.
   - Understanding the trend and planned resource loading is critical, as productivity is affected depending on the operating resource loading level per Queuing Theory.
   - This area may or may not be the domain of QPMI depending on how responsibilities are partitioned if an existing PMO is operating, but nonetheless, it needs to be managed. Resource Loading is a factor that can negatively impact initiatives' probabilities of success in the portfolio. Resource utilization metrics, especially the forecast resource utilization into the future; it is critical for determining the pipeline of initiatives for a portfolio.

22) When should initiatives be scheduled for execution to optimize throughput?
   - *Throughput* is defined as the speed at which initiatives are completed, delivering units of work in the Agile world.
   - A roadmap needs to be established to schedule the launching of new or paused of initiatives. This roadmap should consider:
     - Statistical State of the Portfolio – is the portfolio statistically stable?
       - Starting new initiatives with a statistically unstable portfolio will only compound the negative effects of the portfolio and further delay initiatives.
     - Resource Loading Level.
     - Capacity of the Critical Chain for the portfolio.

23) Where is the "low hanging fruit"?
   - Are there initiatives with high a probability of success and high Prospective Value with minimum risk and cost with short to medium duration (as defined by the PGB) that should be executing right away?
   - If so, what initiatives should be suspended to make room for the new ones, or should the initiative be outsourced?
     - Outsourcing also has an incremental tax on internal resources that needs to be accounted.

24) Will the portfolio provide for the company's needs into the future?
   - Operating Cash flow.
   - Compliance adherence.
   - Keep up and increase customer satisfaction – critical in competitive businesses.
   - Develop products or services ahead or at least in line with competitors regarding features, cost, and usability.
   - What types of utility values are expected to be created by the portfolio the next year, two years, and longer term?

- What is the probabilistic distribution for the generation of each of these type of utilities, their corresponding assumptions, and stochastic models?

25) What are the filters and corresponding processes for the inclusion of initiatives in the portfolio?
    - What are the rules and parameters required for accepting an idea as a candidate initiative for inclusion in the portfolio?
    - Other questions related to the portfolio filtering process are:
        - What is the lead-time from idea submission to initial approval or denial to proceed to the next filtering phase? Is this time statistically stable?
        - What is the probabilistic time duration in between all filters? Is it statistically stable?
        - How is duration trending?
        - What is the drop rate of ideas, initiatives at each filter? Is it stable?
        - What is the number of times an idea is re-evaluated at each filter? Is it Stable?

26) What is the process for how initiatives are entered and exited from the Portfolio Process Life Cycle?
    This process is different than the one address by question 24). Every portfolio must have a process to add, pause, restart, and cancel initiatives. In addition, the second part of this question is what the metrics for the process are.
    - What is the rate of arrival of new initiatives? Is it stable?
    - What is the rate that initiatives are paused? Is it stable?
    - What is the rate that initiatives are canceled? Is it stable?
    - What is the deviation in completion percentage for completing initiatives versus cancel ones?
        - Is it stable?
        - What is the trend?

27) Value Generation

    Value generation management is the primary aim for portfolio management, regardless of the type of assets in the portfolio, i.e. stocks, bonds, loans, initiatives. The ultimate goal is maximizing value creation. Without optimum value generation, the portfolio is underperforming, even if all initiatives are always completed on time, budget, and scope; it does not matter, what matters is generating the maximum value by the right selection of initiatives considering all variances and constraints in the portfolio, the individual risk and correlation of risk among initiatives.

    The value generated from executing an initiative is delivered gradually in the short and long-term after completion. From the perspective of QPMI, initiative completion is not the end, but the beginning of a new phase requiring management and monitoring to determine if value is being realized as predicted, and if not, why not? Understanding this rationalization is critical for future planning, the learning process depends on closing the loop between planning and actual end results. The aim is the continuous improvement of forecasting techniques for Prospect Value, systematically and analytically analyzing the reasons why some "value" was not created or generated as fast as originally planned; then adjusting as needed on future product roadmaps.

    - What value is expected to be generated in the short and long-term under current planning?
        - What is the expected value to be created in the next quarter, six months, and year per utility type?
        - Each product, service, or business process resulting from an initiative should have defined associated value-gathering metrics and stochastic models in the planning phase. Those metrics must be measured before and after delivery to quantify the performance delta and normalized utility value. For example:
            - If a product or service is expected to generate a specific amount of sales over the following year, what is the actual performance versus estimated value? Is

it within expected variation? To answer this, having prior performance metrics is a requirement.
    - Customer satisfaction is expected to increase by some amount within a given period. What is the before and after performance? Is it within the expected variation and planned value?
    - Decrease number of outages in IT, same concept as the previous two.
  - For the sample scenarios described above and equivalent value propositions, it is necessary that an initiative's utility is normalized to enable comparisons among different initiatives. For example, consider the case that requires the comparison of two initiatives whose primary expected utility attribute is compliance. The achievement of 100% value delivery of compliance for one initiative is not necessarily greater than one that achieves 50 or 75 percent; it depends on the utility to the organization, the utile for compliance delivered by one initiative can be significantly higher than the other. The latter normalization of utility is accounted for if using an MAUT derived method for estimating an initiatives' value.

- Is Value being generated as planned?
  - Each product or service has a planned value, utility. What is the rate of value creation by all the services and products in the portfolio compare to the planned value?
  - Is the rate of value delivery for a given initiative within the forecasted expected value and variance? If no, what are the main reasons for the difference?

- What are the investment and on-going operational costs associated with the value generated per utility type?
  - Are operational costs in line with the planned budget? If no, what are the primary reasons for the deviations and the contributing weight of each reason to the difference between planned and actual cost?

28) What is the Technical Debt for the Portfolio?

Technical Debt is an inventory of pending work associated with technical IT products, services, infrastructure, and processes. This type of inventory is usually no transparent to business executives, but it is a primary concern for managing a maintaining a stable portfolio of IT initiatives. Technical debt is created for every IT initiative, there are different types of technical debt, including but not limited to:

- The number of outstanding bugs per severity level. Each bug has an estimated time range to fix the item.
- The number of requirements, user-stories, etc. associated with pending architecture enhancements within an IT initiative. The existence of each of these work-items is part of the natural evolution of software development and infrastructure projects; the most common ones are scaling, stability, performance, availability, maintainability, etc.
- The number of pending Unit and QA automation tests, back-end test scripts, etc. Technical debt associated with increasing the reliability and speed of software delivery.

Accumulation of Technical Debt has two negative consequences:

- Decrease throughput at the micro level. The impact can be dramatic and easily account for 50% of the available throughput for a team.
- Technical Debt is a type of non-linear behavior, which can severely impact the initiative upon entering a state of chaos.

Technical Debt has a non-linear behavior, as the debt accumulates for any initiative, it becomes increasingly harder to do new work, meet performance requirements, scale, sustain high availability, and add new functionality among others. Most of the time, Technical Debt rears its terrible appearance unexpectedly, like an outlier effect; in mathematical lingo, the system becomes chaotic overnight and similar to earthquakes, there is no distinctive sign of an incoming event. Technical debt can accumulate for a long time without an adverse side effect, yet it appears when least expected; it can also manifest itself by ever increasing long cycles of delivery, decrements in performance, etc. All the previous scenarios can put an entire product, service, and infrastructure in jeopardy.

QPMI is concerned with Technical Debt, because of its potential to affect planning and critical initiatives, as an outlier event whose timing cannot be determined, and impact easily quantify. Monitoring and managing technical debt to a state of statistical control is highly recommended; what the maximum level or operating range for technical debt depends on each product, the more complex and monolithic the system, the greater the risk.

1. What is the Technical Debt associated with the portfolio? In monetary value, regarding requirements and user stories?
2. What is the Technical Debt for each product, service, etc. in the portfolio?
3. Is the Technical debt for the portfolio statistically stable? If it is increasing, what is the trend and rate of cost accumulation?

29) What is the status of the portfolio?
   - What is the probability of success of each initiative and the portfolio for cost, duration, and value creation?
   - What is the probability of success for each initiative accounting for all types of variations?
   - What is the cost variance for each initiative as planned versus an actual target of 80 or 90 percent probability of success, and for the portfolio?
   - What are the trending statistics for the probability of success of each project, initiative, and the portfolio? Is it statistically stable?
   - Operational cost for each initiative and the portfolio, is it statistically stable?

3.1.12 Benefits of QPMI

An effective QPMI system provides tangible and intangible benefits to the organization based on the maturity level of the portfolio process achieved.

Primary Benefits:

- Organizational Change Management
- Strategic Alignment
- Value Management
- Value Delivery Management
- Value Balancing
- Risk Analysis and Management
- Termination of Initiatives
- Pipelining of Initiatives
- Systematic Decision-Making
  - Analytical versus intuitive
  - Defensible - Auditable
  - In alignment with organization’s goals, strategy and risk tolerance
  - Accountability
  - Clearly defined process
- Efficient Resource Allocation & Initiative Allocation
  - How much should we do?
  - What is the point of diminishing returns, what is the impact of current resource loading to ongoing initiatives?
  - What is the optimum operating throughput regarding initiatives, resource loading, etc.?

- Consistent Performance & Growth Over Time

Tangible Benefits:

- Adopting QPMI creates a shift away from one-off, ad hoc approaches to portfolio management.
- Establish practices based on visibility, standardization, Portfolio Management Theory, Bayesian Analysis, Decision Management Science, Deming's and Goldratt methodologies for continuous improvement and understanding of variation and system theory.
- By emphasizing the goal of creating the most likely value for the resources available, the portfolio promotes a culture of lean operation, with goals like eliminating waste as you work your way through initiatives.
- Establish continuous improvement processes to discover and eliminate roadblocks to increasing throughput.
- Even the workload for people and teams; optimizing for the entire organization, not just one area.
- Obtained desired results in the shortest time and at the optimum cost – goal is to maximize the throughput (rate of Prospective Value creation) and the initiatives that create the most probable value given the portfolio's constraints.
    - At the strategic level, execution of a set of initiatives selected to optimize maximum Prospective Value for an organization's investment philosophy based on Modern Portfolio Theory.
        - Initiative selection and alternatives evaluation are primary concerns of QPMI.
    - Optimization of initiative execution provides another major influencing factor to reduce cost and increase speed. The primary factors impeding the speed of initiative's execution completion, include but are not limited to:
        - Parkinson's Law
        - Multi-Tasking
        - Student's Syndrome
        - No accounting for Aleatory and Epistemic Uncertainty
        - No accounting for Common and Special Cause Variation
        - Staff seniority
        - Inclusion of personnel availability in all planning
        - Use of effective project management methodologies
        - Organizationally structure and policies
        - Access to require tools and physical environments
        - Multi-project dependencies
        - Lack of Road-Runner mentality – Milestone Centric versus finish ASAP
        - Poor or non-existent Test-Driven development culture
        - Accountability
- Minimizing the inventory of partially completed work.
- Visibility into the risk profile of each initiative and potential impacts on value, cost, and duration.
    - Ability to plan for contingencies as a result of Risk Analysis (Budget, Resources, Reprioritization, etc.).

Benefits for Executives & the Business:

- Optimization of resource allocation.
- Standardizes metrics/methods for initiatives forecasting and tracking.
- Improve communication throughout the organization.
- Promotes accountability for initiative's investments and decision-making transparency.
- Forces executives toward consensus on policy-level issues.
- Standardizes and implements quantitative operating risk profile for initiatives and the portfolio.
- Contingency planning base on resource-loading and risk analysis.
- Focus on value creation.

Benefits for Program Managers:

- Fewer redundant and overlapping projects.
- Promotes objectivity for initiative selection and prioritization.
- Quantitative tracking of project time, expenditures, and risk.
- Facilitates inter-project coordination.

Benefits for Project Managers:

- Facilitates communication needs, escalation, rational for projects.
- Promotes leveraging reusable project information.
- Clarifies project objectives and goals.
- Forces executives and sponsors to accept responsibility for project risks and to understand the impact on schedule and cost.
- Forces executives and sponsors to become familiar with the primary failure of projects: Uncertainty which comes in general in two different forms for any process
    - Common Cause Variation -- IT Project Examples:
        - Variability of estimates on development tasks. Programming is an empirical function, a type of knowledge work. The greater the complexity of the task to be developed, the greater the expected variability.
        - Variability in requirements. Requirements are fully flushed out during development and analysis of a project. It is impossible to predict and plan for all requirements ahead of time; this is one of the principles and accepted reality in Agile. The consequences of this fact, it is that product and project requirements have an inherent variability in them, which is only flushed out during development and testing.
    - Special Cause Variation: IT Project Examples
        - Reliance on unproven technology for the project.
        - Critical resources availability (e.g. sick time, employee turnover).
        - Change in regulations.
        - Dependency on external companies, parties with different timelines and priorities, which will be performing essential aspects of the project.
        - The ability of chosen technology stacks to meet requirements.
        - Ability to migrate and train clients within a plan's schedule.
        - For multi-task resources with operational duties, their ability to focus on the project, directly impacting the ability to forecast a project.
- Standardize practice for risk analysis and financial metrics for the project.

4.0 References

[1] D. Kahneman and A. Tversky, “Intuitive judgment: Biases and corrective procedures,” in A Manual for Encoding Probability Distributions, C.-A. S. Stael von Holstein and J. E. Matheson, Eds. Palo Alto, CA: SRI Int., 1979, pp. 97–125.
[2] D. Kahneman, P. Slovic, and A. Tversky, Judgments Under Uncertainty: Heuristics and Biases. Cambridge, U.K.: Cambridge Univ. Press, 1982.
[3] Concepts, ideas, and minor excerpts for clarification from Karen Goulart, Deming, Walter Shewhart, Donald Wheeler, Kahneman, etc.
[4] A Manual for Encoding Probability Distributions, C.-A. S. Stael von Holstein and J. E. Matheson, Eds. Palo Alto, CA: SRI Int., 1979.
[5] New Tools for Decision Analysis, PART A: SYSTEMS AND HUMANS, VOL. 36, NO. 5, SEPTEMBER 2006, by Konstantinos V. Katsikopoulos, Member, IEEE, and Barbara Fasolo
[6] R. L. Keeney, “A decision analysis with multiple objectives: The Mexico City airport,” Bell J. Econ. Manage. Sci., vol. 4, no. 1, pp. 101–117, 1973.
[7] R. L. Keeney and Howard Raiffa, Decisions with Multiple Objectives: Preferences and Value Tradeoffs, 1993.
[8] R. L. Keeney, Value-Focused Thinking: A Path to Creative Decision Making, 1996
[9] W. Edwards, “How to use multi-attribute utility measurement for social decision-making,” IEEE Trans. Syst., Man, Cybern., vol. SMC-7, no. 5, pp. 326–340, May 1977.
[10] John Thorpe, The Information Paradox: Realizing the Business Benefits of Information Technology, 2003
[11] James Shanteu, Barbara Mellers, David Schum, Decision Science and Technology: Reflections on the Contributions of Ward Edwards
[12] J. S. Hammond, R. L. Keeney, and H. Raiffa, Smart Choices: A Practi- cal Guide to Making Better Decisions. Boston, MA: Harvard Business School Press, 1999.
[13] A METHODOLOGY FOR PROJECT RISK ANALYSIS USING BAYESIAN BELIEF NETWORKS WITHIN A MONTE CARLO SIMULATION ENVIRONMENT, by Javier F. Ordóñez Arízaga, Doctor of Philosophy, 2007
[14] E.T. Jaynes, Probability Theory: The Logic of Science, 2003
[15] Marco Scutari, Bayesian Networks: With Examples in R, 2014.
[16] Horst Rinne, The Weibull Distribution: A Handbook, 2008
[17] William J. Steward, Probability, Markov Chains, Queues, and Simulation: The Mathematical Basis of Performance Modeling, 2009
[18] Kenneth Chelst, Value-Added Decision Making for Managers, 2011
[19] Alessio Ishizaka, Multi-criteria Decision Analysis: Methods and Software
[20] Ronald A. Howard, Foundations of Decision Analysis, 2015
[21] David C. Skinner, Introduction to Decision Analysis (3rd Edition), 2009
[22] Norman Fenton, Risk Assessment and Decision Analysis with Bayesian Networks, 2012
[23] M. Granger Morgan, Max Henrion and Mitchell Small, Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis
[24] Ibe Oliver, Markov Processes for Stochastic Modeling, Second Edition, 2013
[25] Jeff Gill, Bayesian Methods: A Social and Behavioral Sciences Approach, Third Edition
[26] Tristan Boutros and Tim Purdie, The Process Improvement Handbook: A Blueprint for Managing Change and Increasing Organizational Performance, 2013
[27] Ward Edwards, Advances in Decision Analysis: From Foundations to Applications
[28] Robert Wrinkler, An Introduction to Bayesian Inference and Decision, Second Edition, 2003
[29] Taleb, Nassim Nicholas, The Black Swan: Second Edition: The Impact of the Highly Improbable
[30] John W. Pratt, Howard Raiffa, and Robert Schlaifer. Introduction to Statistical Decision Theory
[31] Dennis V. Lindley, Understanding Uncertainty, 2013
[32] Andrew Gelman and others, Bayesian Data Analysis, Third Edition, 2013.
[33] Pierre Simon Laplace, A Philosophical Essay on Probabilities (Classic Reprint), 2012

[34] Sharon Bertsch McGrayne, The Theory That Would Not Die: How Bayes' Rule Cracked the Enigma Code, Hunted Down Russian Submarines, and Emerged Triumphant from Two Centuries of Controversy, 2012
[35] H. William Dettmer, The Logical Thinking Process: A Systems Approach to Complex Problem Solving
[36] Deming, W. Edwards, The New Economics for Industry, Government, Education - 2nd Edition, 2000
[37] Deming, W. Edwards, Out of the Crisis, (Classic Reprint) 2000
[38] Henry Neave, The Deming Dimension, 1990
[39] Blitzstein, Joseph K., Introduction to Probability, 2014
[40] Walter A. Shewhart, Economic Control of Quality of Manufactured Product, (Classic Reprint) 2002
[41] George, Michael, Lean Six Sigma for Service: How to Use Lean Speed and Six Sigma Quality to Improve Services and Transactions
[42] Sivia, Devinderjit, Data Analysis: A Bayesian Tutorial, 2006
[43] William W. Scherkenbach, Deming's Road to Continual Improvement, 1991.
[44] Kotter, John P., Leading Change, 2012
[45] Harvard Business Review, HBR's 10 Must Reads on Change Management, 2011
[46] Donald Wheeler, Making Sense of Data, 2003
[47] Donald Wheeler, Understanding Statistical Process Control, 2010
[48] Donald J. Wheeler, Understanding Variation: The Key to Managing Chaos, 2000
[49] Donald J. Wheeler, Twenty Things You Need to Know, 2008
[50] Forrest W. Breyfogle, Implementing Six Sigma, Second Edition: Smarter Solutions Using Statistical Methods, 2003
[51] Lepore, Domenico, Deming and Goldratt, 1999
[52] Gerald I. Kendall, Advanced Project Portfolio Management and the PMO: Multiplying ROI at Warp Speed, 2005
[53] Gerald I. Kendall, Advanced Multi-Project Management, 2012
[54] Kahneman, Daniel, Thinking, Fast and Slow, 2013
[55] Nate Silver, The Signal and the Noise: Why So Many Predictions Fail--but Some Don't, 2015
[56] Jez Humble, Joanne Molesky and Barry O'Reilley. Lean Enterprise: How High Performance Organizations Innovate at Scale, 2015
[57] Steve Tendon, Hyper-Productive Knowledge Work Performance: The TameFlow Approach and Its Application to Scrum and Kanban, 2015
[58] Rother, Mike. Toyota Kata: Managing People for Improvement, Adaptiveness and Superior Results, 2009
[59] Kodukula, Dr. Prasad, Project Valuation Using Real Options: A Practitioner's Guide, 2009
[60] Clemen, Robert T., Making Hard Decisions: An Introduction to Decision Analysis, 1997
[61] Leach, Lawrence P., Critical Chain Project Management, 2014
[62] Richard M. Bayney, Enterprise Project Portfolio Management: Building Competencies for R&D and IT Investment Success, 2012
[63] Prasad Kodukula, Organizational Project Portfolio Management: A Practitioner's Guide, 2014
[64] H. Markowitz, Portfolio Selection: Efficient Diversification of Investments, 1971
[65] Project Management Institute, The Standard for Portfolio Management – Third Edition, 2013
[66] http://www.prioritysystem.com/tools.html
[67] Kendrick PMP, Tom., Identifying and Managing Project Risk: Essential Tools for Failure-Proofing Your Project, 2009
[68] Scheinkopf, Lisa J., Thinking for a Change: Putting the TOC Thinking Processes to Use
[69] Gary Gruver, Tommy Mouser, Gene Kim. Leading the Transformation: Applying Agile and DevOps Principles at Scale, 2015
[70] David J. Anderson, Kanban, 2013
[71] Sam L. Savage, Jeff Danziger, Harry M. Markowitz., The Flaw of Averages: Why We Underestimate Risk in the Face of Uncertainty, 2012
[72] Eliyahu M. Goldratt, Critical Chain: A Business Novel, 1997
[73] Eliyahu M. Goldratt, The Goal: A Process of Ongoing Improvement
[74] Henrik Kniberg, Lean from the Trenches: Managing Large-Scale Projects with Kanban, 2011
[75] Kenneth S. Rubin, Essential Scrum: A Practical Guide to the Most Popular Agile Process, 2012
[76] Ilan Goldstein, Scrum Shortcuts without Cutting Corners: Agile Tactics, Tools, & Tips, 2013
[77] Anthony O`Hagan, Uncertain Judgments: Eliciting Expert's Probabilities, 2006

[78] Granger Morgan, Use (and abuse) of expert elicitation in support of decision making for public policy, http://www.pnas.org/content/111/20/7176.full
[79] Ian T. Jolliffe, David B. Stephenson, Forecast Verification A Practitioner's Guide to Atmospheric Science, 2011
[80] Philip E. Tetlock, Superforecasting: The Art and Science of Prediction, 2015
[81] Malaquias Espena, Ensemble Forecasts and their Verification, http://www.atmos.umd.edu/~ekalnay/syllabi/AOSC630/ensemble101.pdf
[82] Riccardo Rebonato, Why We Need to Manage Financial Risk Differently – Plight of the Fortune Tellers, 2007
[83] Riccardo Rebonato, Portfolio Management under Stress: A Bayesian-Net Approach to Coherent Asset Allocation, 2014
[84] Alexander J. McNeil; Rüdiger Frey; Paul Embrechts; Quantitative Risk Management: Concepts, Techniques, and Tools, 2015
[85] Nassim Nicholas Taleb, Fooled by Randomness, 2005
[86] Terje Aven, Risk, Surprises and Black Swans: Fundamental Ideas and Concepts in Risk Assessment and Risk Management, 2014
[87] Terje Aven, Reliability Engineering & System Safety Volume 121, January 2014, Pages 1–10, A new perspective on how to understand, assess and manage risk and the unforeseen
[88] Terje Aven, Reliability Engineering & System Safety Volume 134, February 2015, Pages 83–91, Implications of black swans to the foundations and practice of risk assessment and management
[89] Lars P. Syll, Paul Davison, https://larspsyll.wordpress.com/2012/07/29/keynes-and-knight-on-uncertainty-ontology-vs-epistemology/ , 2012
[90] Peter P. Wakker, Prospective Theory: For Risk and Ambiguity, 2010
[91] Daniel Kahneman, Choices, Values, and Frames, 2000
[92] https://en.wikipedia.org/wiki/List_of_banks_acquired_or_bankrupted_during_the_Great_Recession
[93] http://www.aei.org/publication/charts-of-the-day-creative-destruction-in-the-sp500-index/
[94] https://www.infoq.com/articles/standish-chaos-2015
[95] Ariel Caticha, Lectures on Probability, Entropy and Statistical Physics, https://arxiv.org/pdf/0808.0012v1.pdf 2008
[96] Ariel Caticha ENTROPIC INFERENCE AND THE FOUNDATIONS OF PHYSICS http://www.albany.edu/physics/ACaticha-EIFP-book.pdf 2012
[97] James V. Stone, Information Theory: A Tutorial Introduction, 2015
[98] Benoit Mandelbrot, The Misbehavior of Markets: A Fractal View of Financial Turbulence, 2006
[99] The use of Bayes and causal modeling in decision making, uncertainty and risk, by Norman Fenton and Martin Neil, 2011 http://www.agenarisk.com/resources/white_papers/fenton_neil_white_paper2011.pdf
[100] Managing Risk in the Modern Word, Applications of Bayesian Networks, by Norman Fenton and Martin Neil, 2007 http://www.agenarisk.com/resources/apps_bayesian_networks.pdf