

HANDBOOK OF
DECISION
MAKING



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Decision Errors of the 4th, 5th, and 6th Kind

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INTRODUCTION

Most people are familiar with Alpha or Beta errors from statistics or even error of the third kind (Mitroff and Betz, 1972). Alpha errors arise when we reject a true hypothesis and Beta errors arise when we 'fail to reject' a false hypothesis. 'Errors of the third kind' arise because managers, when faced with a decision often solve the 'wrong' problem very precisely. Here we expand on these concepts by drawing attention to errors of the 4th, 5th, and 6th kind.

VISIONING ERROR, CORRELATION ERROR, AND ACTION ERROR

Clawson (2009) describes 'the leadership point of view': seeing what needs to be done; understanding the underlying relationships and forces at play, and having the courage to initiate action. This framework covers the basic things a leader must do. Decision errors can similarly be separated into three kinds that parallel this leader/decision maker model: 'visioning errors', 'correlation errors', and 'action errors'. Firstly, visioning errors may be made when deciding what the main problem is that needs to be fixed. Such meta-level errors are those described by Mitroff and Betz (1972) as errors of the third kind. Secondly, correlation errors may be made when interpreting data and other evidence while figuring out causes of problems, and relationships between the various forces at play. These errors are the classic Type I (α) and Type II (β) errors described by Neyman and Pearson (1928, 1933). Thirdly, action errors may occur when deciding whether or not, and when, to act. These action errors we will describe as errors of the 4th and 5th kind. Finally, a dangerous compound error of the 6th kind may be made when particular combinations of error mistakenly introduce new forces that have unforeseen interactions and impact outside of the field of attention.

Visioning errors happen when managers are deciding what the problems or issues are that need to be addressed. When managers do not notice, fail to consider a live hypothesis (James, 1896), or fail to pay attention to main issues and levers, and instead focus attention and effort on subordinate or inconsequential issues, then they have made *visioning errors*. Seeing what needs to be done means discerning which problems are tightly linked to the prioritized outcomes they hope to bring about. When management focuses upon corollary problems that only indirectly impact desired outcomes, or when attention is limited to effects of root problems rather than the root problems themselves, then management is committing errors of vision. Mitroff and Betz (1972) labeled the mistake of working on the wrong problem or issue an 'error of the third kind'.

Correlation errors occur when pondering, testing, and deciding about relationships between variables such as existing forces, possible actions, and potential outcomes related to a problem. Type I (or α) errors occur when the null hypothesis is mistakenly rejected – we mistakenly reject that there is no relationship between the variables. In other words, there is not in fact sufficient evidence to support the hypothesis, but we mistakenly decide that the evidence does support the hypothesis. It is not unusual to find managers believing they have evidence that 'A' is the cause of 'Problem B,' when there is in fact actually not sufficient evidence of a relationship.

Action errors occur when deciding whether to act on a proposed solution. Managers, after deciding what needs to be done, face a decision of whether or not to take action. There are two kinds of action errors: actions that you should have taken and actions that you should not have taken. Action error *does not* occur in cases (1a) when action is taken when action is truly needed, and (1b) when action is not taken when it is not appropriate. Action error *does* occur (2a) when action is taken, when it should not be taken, and (2b) when action is not taken when it should be taken.

Certainly there are multiple possible causes for a manager, having already decided what might be done *about* a problem, to then either act or not act. Sometimes a manager acts on a correct decision about what needs to be done, and the problem gets solved. When managers fail to act, often this is in the belief that systems and procedures are already in place to solve the problem at hand. Sometimes managers decide not to act because they believe that the problem will simply go away, or at least fade into inconsequence, if they exercise patience and wait it out. In either case, the decision to act or to forebear may be the correct decision.

Another possibility is that the decision to act, or the decision not to act, is a mistake that leads to unintended consequences. We introduce these as errors of the 4th and the 5th kind.

CONCATENATION OF VISIONING ERROR, EVIDENCE ERROR, AND ACTION ERROR

There is certainly no guarantee that only one kind of error is committed per problem. After all, there are three possible genres of error, and it is possible for management to make all three kinds of error, none of the errors, or any combination. Poor decision makers (or those with bad luck) might find themselves

all too often working on the wrong problem, accepting unfounded cause and effect relationships, and then acting when they shouldn't. What happens when these different kinds of errors interact when working on a problem? There are $2 \times 3 \times 4 = 24$ (twenty-four) possible combinations to examine. The two (2) covers the bimodal situation of 'vision error' and 'no vision error'. The three (3) counts 'no correlation error', 'Alpha error', and 'Beta error'. The four (4) covers the action possibilities: 'no nonaction error', 'no action error', 'action error', and 'nonaction error'.

Below, we use a decision tree (Figure 12.1) to diagram the paths and interactions of this three-part decision-making process. We use the standard binomial notation of '0' for an error and '1' for a correct decision at each of the three levels through the decision tree. The labels 'Right, 1' or 'Wrong, 0' on the first decision stand for the correct decision to work on the *right problem* and the incorrect decision to work on the *wrong problem*. The next level of labels covers possibilities when analyzing evidence, testing for correlations, and possible cause-effect relationships. 'No Error, 1', 'Wrong (α) 0,' and 'Wrong (β) 0' are the labels for the three possible decisions about correlation among the data: a right decision about what the evidence/data shows; a Type I error of believing in a correlation that does not exist; or a Type II error of not believing in a correlation that does exist. The third level of labels stands for the possible action errors. An 'a' stands for acting, and a 'w' stands for waiting. A '1' means that it was the correct action decision, and a '0' indicates an incorrect action decision. Thus a path of '1, 1, 1_a' stands for 'right problem, causes understood, take action that is needed'. A path of '1, 1, 0_a' indicates 'right problem, causes understood, unnecessary action taken'. Other combinations are less simple to understand, but no less likely to occur. For example a '1, 0, 1' combination indicates working on the right problem, then making either an alpha or a beta

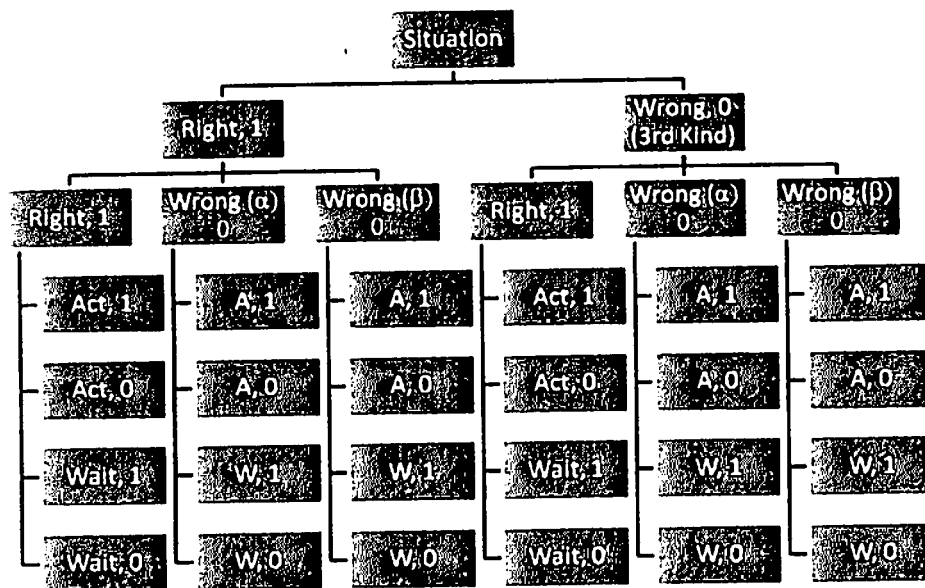


FIGURE 12.1 Decision tree for vision error, correlation error, and action error.

correlation/causation error, and then making a *seemingly* correct action decision, but one that is based upon the mistaken assumption that the causes and effects of the problem are properly understood, even though decisions about the causes were *in fact* in error. For a complete summary of all possible paths, the type of error they are associated with, and what they mean, see Appendix III.

Using this decision tree allows for probabilities to be calculated using the binomial distribution. The odds of each decision path are simply dependent upon the probability that each kind of error is made at each step. For example if there are a host of problems facing a manager, there is a possibility that management will work on the wrong problem. Perhaps a manager quite good at recognizing and prioritizing problems is right 80 % of the time. Further assume that this manager is a stickler for an audit trail, making sure that all the reasonably available evidence is gathered, correctly measured, and tested, so we assign a 0.9 probability that no correlation error will be made when analyzing the evidence, with a 0.05 chance of Type I error and 0.05 chance of Type II error. Finally, assume that this manager is good at knowing when to act, when to withhold action, and has the courage to act when it is indicated. If we then assign a 0.95 probability this good decision maker does not make a Type IV error or a Type V action error then *there is only a 68.4 % chance ($0.8 \times 0.9 \times 0.95$) that a very good decision maker like the one we have assumed will make no errors*. One would expect that a more average decision maker would have a lower probability of making the right decision. Nutt (1999) reports that half of the decisions made in organizations fail, and we do not find this claim surprising.

NO ERROR

The ideal situation is when no decision errors are made. There are two paths in the decision tree like this, noted by a 1, 1, 1 score. The first describes the competent take charge leader making no errors. In this cell, the decision may be assumed to be sufficiently solved with no enduring problems connected to the solution.¹ Leadership has done at least three things correctly. Firstly, management is working on the right problem. They have had clear enough macro-vision to see what needs to be done and not get distracted into working on subordinate, associated, or inconsequential problems. Secondly, management has gathered enough of the proper evidence/information to discern fact from belief, desire, and fiction, and to uncover true correlations among the forces involved from apparent but nonexistent correlations, and to locate true causes from among the many effects and correlates. Thirdly, management has acted upon this evidence because there is not another effective curative process already underway.

The second 1, 1, 1 path is similar to the first in all respects except that management has the good judgment to refrain from taking action, even though the causes of the problem are now understood: This might be described as the 'Good decision, no action, problem solved' path. Refraining from action may be the proper decision for a variety of reasons. Firstly, the problem may be the type that just goes away if one waits it out. Dealing with the common cold and or an employee's occasional bad mood seems to fall into this category of problem. Burgelman and Grove

(1996) describe how various instances of dissonance require no action, (unless it is 'strategic dissonance'). Leaders, they say, should know their organizations well enough to discern between ordinary dissonance that is best ignored and will go away, and strategic dissonance that requires action. Boal and Hooijberg (2001) suggest that discernment lies at the heart of managerial wisdom. It involves the ability to perceive variation in both the interpersonal and noninterpersonal environment. In addition, it involves the capacity to take the right action at the appropriate moment. Secondly, there may be structures and processes in place that will solve the problem if you do nothing. The real question is whether or not the manager can yield to the logic of this path given the 'bias for action' that many managers have. Given a problem, managers may need to defend their reputation as a take charge decision maker, and thus act when they would be better off not acting. Some wisdom on the part of the decision maker is called for if they are to be able to discern between 1_A and 0_A . If they cannot, they may create problems of the third kind or iatrogenic solutions.

ERROR OF THE 1ST KIND (TYPE I)

When attention is focused on the right problem, and no action is taken, the problem can escalate if a Type I correlation error has been made. This is modeled as the $1, 0_\alpha, 1_w$ path. Some argue that President George W. Bush erred early in 2002 in just this (Type I) way when he concluded that Iraq was an immediate terrorist threat based upon evidence of weapons of mass destruction ('WMDs'), when the evidence was not in fact sufficient to support that hypothesis. Another example occurred two years before the October 2008 global financial system crisis that sent equity values down over 40 %, and shut down interbank lending. No later than 2006, both Senators Barack Obama and John McCain had separately spoken about the subprime mortgage crisis, especially how it was affecting Fannie Mae and Freddie Mac (mortgage investment companies), and yet nothing was done. One could argue that the right problem *was* brought to attention, and *was* worked on, but then a Type I error was made. The Senate committee gave too much weight to the evidence pushed forth by Fanny and Freddie Mac lobbyists, who demonstrated a strong inverse relationship between the existing controls and the size of the mortgage asset problem. Leaders were therefore convinced that using the existing control systems more would make the problem less. This was not also an error of non action. That is, action was (correctly) not taken on a problem that (it rationally seemed) *should not have been acted upon* because adequate existing resolution systems *seemed* in place. However, while resolution systems *were* already in place, they were not in fact adequate. The adequacy was (incorrectly) established at the correlation error point, not at the action decision point. Errors are often rooted in this kind of bounded rationality. What we mean is that sometimes action and nonaction decisions are rational at the time of the decision, given the problem as presented and the evidence at hand, but in fact wrong due to error caused by complexity, information equivocality, tunnel vision, and so forth.

ERROR OF THE 2ND KIND (TYPE II)

When a decision path takes the form $1, 0_{\beta}, 1$ it indicates a Type II error. Type II or β errors occur when a hypothesized relationship does in fact exist, but one fails to recognize the truth of the matter. Relying on flawed testing methods, the Union Cycliste Internationale (UCI) erred in just such a way with a series of decisions from 1995 to 2005 that performance enhancing drugs were not significantly influencing the outcomes of races such as the *Tour de France*. The UCI's tests were showing insufficient evidence to claim the presence of illegal performance enhancement supplements when such supplements were in fact present.

In 1985 The Coca-Cola Company decided to abandon their original recipe for Coca-Cola in favor of a new formula. They tested to find out if existing loyal customers would be turned off by the change, and tested if non customers might be more likely to adopt the new product. Unfortunately they made a Type II error, and failed to reject the null hypothesis when testing for an inverse relationship between demand by existing customers and the new coke formula. While they were correct that potential new customers were more willing to adopt new coke than classic coke-cola, they erroneously failed to reject the other null hypothesis, concluding that there was no inverse relationship between changes in the formula and demand from their existing customers. Focused on the right problem (i.e. gaining new customers), Coca-Cola tested for the relevant correlates and made an error, then rationally acted, abandoning the original recipe and launched New Coke (1, 1, $0_{\beta}, 1_{\alpha}$). Type II error can cause serious damage.

ERROR OF THE 3RD KIND (TYPE III)

Ian Mitroff's famous 'Error of the Third Kind' (1972) occurs when the manager is trying to solve the wrong problem very precisely. The manager may be a take charge person, but with blinders on. S/he misdiagnoses the situation, and thinks the problem is one thing when it is in fact another. We call this 'vision error' because it is the result of incorrectly seeing what needs to be done, leaving the 'true' problem outside of the attention of the decision makers. As a result organizational resources are used to solve something (another problem or a non problem), but not *The Problem*. As a result, the original problem lingers. It may do so benignly still requiring a solution, but it may fester requiring greater resources to solve. Organizational decline is often characterized by the process of denial, followed by action involving errors of the third kind, which do not stop the decline. Finally, the real problem is addressed and further action taken. Unfortunately, when the organization gets around to solving the real problem, the problem has festered requiring greater organizational resources to solve but which the organization no longer has, and decline continues.

When there has been an error of the 3rd kind, the solution is at best only indirectly effective, on average irrelevant, and at worst iatrogenic. In the best case, there are already effective administrative structures in place to deal with the true

problem, and the problem gets solved even though it was not addressed by decision makers. In the average case, the true problem remains unaddressed and lingers, yet perhaps remains more or less in check because action is being taken on a related, but wrong problem. In worse cases, the lingering true problem festers, perhaps becoming more difficult to remove. In even worse cases, no action is even taken on related (yet wrong) problems. (This compound situation we describe below as an error of the 6th kind.) An error of the 3rd kind can be quite serious.

ERROR OF THE 4TH KIND (TYPE IV)

Acting to solve a problem, be it the right problem or the wrong problem, can create other difficulties. Sometimes solutions are 'iatrogenic,' meaning that they create more, or bigger, problems than they solve. Faced with such a possibility the decision maker should thoroughly examine all the potential system effects, and perhaps refrain from action.

In the case that it was an attempted solution to the right initial problem, one important problem is now replaced by another, perhaps worse, problem. We might call one who takes this path 'the Iatrogenic Decision Maker'.

Iatrogenic Decision Maker: Here the decision maker takes charge, makes a decision, but the solution to the original problem creates more and greater problems to be solved. This often occurs when the manager can not anticipate the interconnections between elements, especially nonlinear interactions. This may occur because the manager compartmentalizes the decision not foreseeing how the effects may set up other, more difficult problems, or because the manager's time frame is too limited. A classic example is Three Mile Island (Osborn and Jackson, 1988). There was a leak in the coolant system and the valve froze up. They decided to fix the problem by draining the coolant, and this led to the disaster in which the plant went south in a major meltdown. While this is a dramatic example of an iatrogenic outcome, such outcomes are more prevalent than we realize. For example, most medicines give lists of contraindications, i.e. don't use this medicine with that medicine. However, drug companies rarely look past two-way interactions. One of the authors takes five different medications per/day. Yet none of his doctors can tell him if he should be taking the five medications together or not. People who suffer from multiple ailments are always at risk from unknown drug interactions. Some solutions have unknown consequences, but some solutions can be anticipated to cause other problems. Sometimes, because decision makers do not anticipate the futurity of their decisions, focusing on too short a time period, problems that could reasonably be anticipated are ignored. Sometimes, the decision maker might realize his solution will cause other problems, but because he thinks the immediate problem is more important, or he believes the anticipated problem is a bridge to be crossed when it happens, or the stakeholder group is too weak to worry about, s/he will go ahead and make a decision that they know will create more and greater problems for the organization. But, that will be someone else's headache.

Some have argued that President George W. Bush committed this kind of action error of the 4th kind in March of 2003 by initiating (military) action in Iraq when he

should not have. The critic's argument is that even if there were no α -error and Iraq was in fact gathering WMDs, the decision to *act* upon it was in error because broad and powerful international diplomatic systems and control processes were already in place that would have solved or at least contained the problem. Critics point out that President Bush acting when he should not have acted created an iatrogenic outcome, that is, his solution made the problem worse instead of better.

ERROR OF THE 5TH KIND (TYPE V)

Deciding to take no action, when no action is called for, is the correct solution. However, falsely believing that the problem will either solve itself or simply go away is an error of the 5th kind. Such errors allow the situation to linger, at best, or to fester and worsen requiring greater resources to solve. The decision maker on path 1, 1, 0_w might be described as 'the wishful non action taker'. This person mistakenly thinks that if they do nothing the problem will either go away or resolve itself through existing processes and network externalities. What they don't realize is that the problem either will not go away or that the original problem will metastasize and require great resources to solve the longer organization waits. Collins (2001) discusses how the Great Atlantic and Pacific Company (A&P) went from dominating the grocery business in the first half of the twentieth century to an also ran behind Kroger's in the second half of the twentieth century. Despite data that consumers wanted superstores, and that they had a model that worked (Gold Key stores), A&P failed to act because it did not fit their identity. As Ralph Burger, then CEO of A&P said, 'you can't argue with 100 years of success'. Fox-Wolfgramm, Boal, and Hunt (1998) discuss how an organization's identity can lead to resistance to change. Boal (2007) notes that the rules and routines that make up an organization's transactive memory inhibit search, and lead to a misdiagnosis of the problem or non action. Such was the case with Sony when it could not let go of its cathode ray tube (CRT) technology for making televisions, while Sharp, Samsung, and LG Electronics forged ahead producing liquid crystal display (LCD) televisions. Finally, Wetzell and Johnson (1968) discuss how organizational failure and decline is almost always preceded by a denial of reality leading to non action.

While not taking action may be the correct decision, in many managers' eyes a worse outcome is a reputation of lack of courage or initiative to take action. This would be an especially powerful fear if a boss incorrectly believes that you were aware of the problem but chose not to act thereby risking the creation of a bigger problem. This reinforces the schema that managers are problem solvers/decision makers and action takers creating a general bias for action. For the manager/decision maker, there exists a risk management dilemma: which is worse, making an action decision that turns out bad or not making a nonaction decision that allows a problem to evolve into a disaster? In organizational cultures with a bias for action, we would likely find more errors of the 4th kind than errors of the 5th kind. In organizational cultures or structures with a bias for inaction, we would likely find more errors of the 5th kind than errors of the 4th kind.

Sometimes a Type V error takes the form of waiting too long for action. Often it is hoped that not taking action will allow the problem to solve itself or become a non problem. If the decision maker is wrong, s/he hopes that merely delaying the decision will not be fatal and that the problem will stay of the same shape and form requiring the same resources to solve. In other words, the decision makers act as if the problem does not have a time dimension. Often by delaying the decision, greater resources may be needed to solve the problem, but the needed resources are manageable. As long as management's attention is on the problem, it probably will not get too bad before action is prioritized.

ERRORS OF THE 6TH KIND (TYPE VI)

Errors of the 6th kind are compound errors that may occur in three circumstances. Two of them are indicated when an error of the 3rd kind has already been made, and then an action error is made. For example, there is the '0, 1, 0' situation, in which a Type III error has already been made, then the initial problem is still outside of the attention, and so possible negative interactions with it may not have been considered when a manager acts. Not only does the real problem lie untreated and festering, but mistaken action on the wrong problem may introduce new correlates that may create forces that did not previously exist. This compound decision error situation is a Type VI Error ('error of the 6th kind'). In this case action creates more problems than it solves and allows other problems to combine in new ways and morph into a qualitatively different problem.

The other Type VI error circumstance takes the 1, 0, 0 form. For example '1, 0a, 0a,' notes a decision path of working on the right problem, seeing a cause that does not exist, and then acting when one shouldn't. By introducing new forces into a group of previously uncorrelated forces, new correlations and unexpected outcomes occur. It is possible that the US-led war in Iraq initiated by President George W. Bush on March 21, 2003 followed this particular path. In terms of our model, a Type I error (of believing in the existence of WMDs) combined with the Type IV error (acting when he should have allowed existing processes to solve the problem) resulted in a Type VI Error. This 'error of the 6th kind' may have introduced new forces that combined with existing variables in unforeseen ways. The outcome provides possible evidence that this was a Type VI error: a morphing of the initial hidden terrorism cell problem into a major occupation style war, foreign government building initiatives, massive dept increases, economic hardship, and a global loss of power and influence for the USA.

In cases when one of the two action errors (non action, when action should have been taken, or action when action should not have been taken) are made on the 'wrong' problem, the true problem will likely morph into something unrecognizable in terms of the original problem. Unlike errors of the 4th kind, which cause escalation of the problem, or errors of the 5th kind, which give problems time to fester, these 'error of the 6th kind' paths allow problems to grow qualitatively as well. Errors of the 6th kind often result in situations where the problem resolution does not just require more resources, but entirely different resources altogether.

If the right problem is not noticed, and no action is taken, the problem can morph into a new shape and form if a Type I correlation error has also been made. This would be the 0, 0a, 1_w path situation. Expanding on our Type I error example from above, when senators Barack Obama and John McCain brought to the US Senate the issue of how sub-prime loans might negatively affect Fannie Mae and Freddie Mac and nothing was done, one might argue that not only were they wrong that the VaR (value at risk) model was inadequate (Rickards, 2008) and other control systems would solve the problem (as lobbyists reportedly convinced them), but that they were working on the wrong problem altogether. The senate worried about Fannie Mae and Freddie Mac, and did not focus on the root: mortgage brokers selling and then under-disclosing loan default risk, and consumers and businesses engaging in loans that they could not afford if even a small downturn were to occur, either in their lives or in the general economy. A problem was brought to attention, and worked on. Then the subsequent Type I error was of believing in a strong inverse relationship between the existing control systems and the problem was made, so that leaders thought just using the existing control systems more would make the problem less. The US Senate did not attend to the bigger or root problem, and furthermore erroneously concluded that the existing control systems were adequate for this (wrong) problem. They then made the rationally correct decision not to act.

The above kind of situation shows how complicated an error of the 6th kind can be, and how easy it is for leaders to make them. The error was (a) vision: did not consider the broader macro-systems effects combined with (b): did not have enough clear and relevant information about forces and relationships involved.

Another example, related to the 2008 financial crisis was when no one knew that Lehman was shorting firms, and covering the short sales with treasury stock it had just taken as collateral for lines of credit to those very firms it was shorting. Even the firms who gave them the collateral did not know Lehman was going to float those shares on the market, desperate to make some money to hold them over. This Type VI error is decision error of the 3rd kind combined with error of the 5th kind (0, 1, 0_w). Regulators (a) did not have vision to see that unethical short-selling was not the important problem, it was firms desperate for cash and about to default on payments; (b) lacked information that Lehman Brothers were short-selling their own clients backed with treasury stock that was collateral they had no right to float, leading to (c) non action resulting in new and worse problems. As a result, Lehman Brothers was eventually left to fail, and many experts in the weeks that followed, including the French Minister of Finance, claimed that this was the event that led most directly to the global financial meltdown of October, 2008. When a Type VI error is made, the resulting problem may no longer be recognizable in its original form. The problems are not easily diagnosable, the resources and choices available become less sufficient or desirable, the solution is not readily apparent, and the solution not so attainable.

Error of the 6th kind creates 'wicked' as opposed to 'tame' problems. Tame problems may be very complex, but they are solvable such as sending a man to the moon. It was a very complex problem, but the individuals could agree upon the definition of the problem and a solution could be found. Wicked problems are ones for

which either the problem cannot be defined or *no* agreement on the solution can be found. Think about the problem of unwed teenage pregnancy. What is the underlying problem? Hormones? Morality? Both? Neither? What is the solution? Birth Control? Abstinence? Where individuals cannot agree on the problem, much less the solution, non action is the likely outcome.

DECISION ERRORS LEADING TO POSITIVE OUTCOMES

We find two decision error combinations that can lead to positive outcomes. These are an error of the 4th kind in the presence of an error of the 2nd kind (β), and an error of the 5th kind in the presence of an error of the 1st kind (α). ' $1, 0_\alpha, 0_w$ ' describes a situation in which leadership mistakenly believes they have identified some causal relationship that if acted upon will solve the problem. If action were taken, the decision maker would be committing an error of the 4th kind. Here however, management mistakenly does not act even when they believe they are supposed to act. Perhaps management is lacking the courage to act, the incentive to act, or just has too much else going on to work on another implementation. Unknown to the decision maker, the evidence was wrong, and by mistakenly not acting, an error of the 4th kind is avoided. Holcombe (2006) details a poignant example of such a situation. He brings to attention decisions regarding global climate change problems circa 1950–1980. Holcombe points out that if we had acted 30 years ago to stem global climate change based upon the best scientific evidence and overwhelming consensus among our best scholars, we would have tried to *warm* the planet, not cool it. By not acting, even when all evidence said we should have, we probably averted making a huge mistake and making the current warming trend worse.

Decision makers in taking the $1, 0_\beta, 0_a$ path take action on some hypothesized cause of a problem even when there is no apparent evidence that this cause or correlation exists. Flying in the face of the apparent evidence, they act anyway. Perhaps we can describe this kind of decision maker as the 'intuitive contrarian' because the evidence was in fact wrong, the causal relationship did exist but was missed (Type II error), and action was actually needed. Through luck, intuition, and perhaps even recklessness an error of the 5th kind is avoided.

Playing off of Holcombe's global climate change in the 1970s decision example, we may at the time of this writing (2008) be in this situation. That is given the complexity of the earth's environment and interacting forces, it is very difficult to gain certainty about what action should be taken to fix the global warming problem, or if action is appropriate at all. However, many now agree that despite not yet being certain that atmospheric CO_2 reductions will solve climate change problems we should nonetheless act aggressively. Despite the live hypothesis that Earth has natural cycles and systems that allow it to take care of itself, most agree that it would be irresponsible and in error not to act. Sometimes, despite the lack of complete information, evidence, and understanding, we decide to act anyway 'before it is too late' – before the problem morphs into new and worse problems. Going with intuition about causes, and taking action without full understanding, we sometimes end up with a positive outcome.

CASE STUDIES

We next summarize two cases in which a number of decisions and decision error possibilities present themselves. The first case study is the financial markets and systems crisis of 2008, as observed no later than October 12, 2008. This means that at the time of writing (October 12, 2008), outcomes of the situation after the stock market(s) crash are unknown, as are many of the details which will later no doubt come to light. Therefore predictions will be made, and decision error possibilities suggested, but the truth will not be known until well after this chapter goes to print. It will hopefully be informative to compare in retrospect the decision errors we proposed were being made (at the time of this writing), with the decision errors that will be borne out by history to be true to the facts. Data for the 'World Financial Crisis, October 2008' case study was collected from the extensive ongoing newspaper, web, and television media coverage of the event as it occurred.

The second case study 'Meltdown in the Tropics' occurred on Tuesday evening, March 3, 1992, making it possible to look backward and analyze the decision paths and errors. On that evening, a manager was involved in an operations 'meltdown'. Fifteen years later, he said, 'I still don't like thinking about it' and it was 'my worst day of work, ever'. Data reported for this case is based upon first hand recollections of the event gathered from the manager involved in the case.

The Appendix contains a table summarizing the possible decision paths and error(s) that we have established above. We refer to this table during our discussion of each case study.

Case 1: World Financial Crisis, October 2008

On July 15, 2008, US Treasury Secretary Hank Paulson and Securities and Exchange Commission Chairman Christopher Cox took radical steps: they created an emergency order limiting short-selling in shares of Fannie Mae, Freddie Mac, Lehman Brothers, Goldman Sachs, Merrill Lynch, and Morgan Stanley. They did this to stop a growing problem that seemed suspiciously close to insider trading, and that was creating unnecessary and unfounded worry among all shareholders that the biggest investment banks in the world were in trouble. VaR (value at risk) models were double checked, and no bank had more at risk than the balance of their assets could easily cover.

Two and a half months later, In October of 2008, the United States Federal Reserve faced a major decision. Should they commit about \$ 1 trillion of the public's money to bail out investment banks holding mortgage and real estate backed assets whose values had plummeted over the last year. Investment banks and mortgage banks were failing at an alarming rate. Morgan Stanley, Fanny Mae, Freddy Mac, and Washington Mutual had already been closed down then sold. Lehman Brothers had been allowed to fail altogether, as no buyer could be found. The other major investment and mortgage banks were on the brink of failure. Even worse, the firms that sold insurance to

these banks providing a hedge against downside risk were also about to declare bankruptcy. AIG, one of the largest of those, had already been rescued; purchased by the US Government to prevent its failure. Leaders of nations and of financial markets gathered and had meetings 24 hours a day in order to figure out what was going on, understand what might be done, and decide what to do, and what not to do about it. The life blood pressure of modern financial systems, the liquidity of assets, and the flow of cash had dropped precariously. The system was on the brink of failure.

On October 9, 2008, the Dow Jones Industrial average had fallen to 8579.19, down from 14 164.53 exactly one year earlier, a 38 % decline. 'On paper' losses for the year, measured by the Dow Jones Wilshire 5000 Composite index which represents almost all of the stocks traded in the USA, added up to \$ 8.3 trillion lost, an almost incomprehensible figure. The US stock market had declined 21 % (2338 points) in just four weeks following the bankruptcy of Lehman Brothers investment bank. Much of this decline (17 %) came in the days *after* October 5, *after* a much debated and passionately defended credit market bailout solution had been announced and enacted. The next day, Friday October 10 the slide continued, dropping another 128 points, down 1874 for the week after the solution was announced.

The US Federal Reserve and EU central banks had agreed to purchase devalued assets, mostly mortgage back securities, held by banks and investment firms and had coordinated a global lowering of interest rates on government loans to banks.

On October 6, the day after the solution had been enacted, the Associated Press' Tom Raum and Jeannine Aversa begin their front page article with: 'On Day One, the \$ 700 billion plan didn't help, just the opposite. The government's huge rescue package, aimed at rebuilding economic confidence in the US and around the world, instead sounded a global alarm. The trading day after Congress approved the measure and President Bush signed it into law (with much fanfare on a Friday), US and world stock markets dropped approximately 7 %' (Raum and Aversa, 2008). There were now pointed questions about how this would all be paid for. The Treasury Department reported it would increase its bond sales to help pay for the bailout, and the Federal Reserve immediately responded by announcing an expansion of the loan bailout program to \$ 900 billion and that it would pay interest on reserves that banks kept at the Federal Reserve.

Raum and Aversa continued: 'Bush sought to reassure panicking markets. "It's going to be awhile to restore confidence in the financial system. But one thing people can be certain of is that the bill I signed is a big step toward solving this problem," he said in San Antonio. Nobody seemed reassured. Chaos in the financial system seemed to grow by the minute.' (Raum and Aversa, 2008: 7) When the Dow Industrial average plunged below 10 000 for the first time in four years that day, all sectors were being sold off en masse, and not just financial and related stocks. 'The crisis has morphed from a near shutdown in lending to a new, more dangerous phase in which financial and other companies face greater chances of insolvency', suggested University of

Chicago Professor of economics and finance Amil Kashyap (Raum and Aversa, 2008: 7).

Three days later, on October 9, when further 'helpful' bailout measures were announced by the federal government, the market dropped another 7 % (679 points), down a full 17 % in the four days since the *solution* to the problem had been announced (Paradis and Crutsinger, 2008).

On October 10, Luis Uchitelle of the *New York Times* News Service wrote:

The Federal Reserve and congress are pushing out close to \$ 1 trillion to repair the nation's financial systems and to encourage lending. But that is not enough to revive the economy. Spending has to resume. Consumers, however have cut back sharply on their spending, in what will be the first quarterly decline in 17 years when the government tally is in for the third quarter. 'We have to prop up consumption,' Rep Barney Frank, D-Mass., chairman of the House Financial Services Committee said in an interview.

Uchitelle's *New York Times* article continued:

The rationale for another stimulus package, particularly one that helps states and cities, is compelling for many economists. The nearly \$ 1 trillion that Congress and the Federal Reserve are making available to the financial system is intended to make credit more available. That props up the supply side. But to make the economy grow, or stop contracting, demand is required. Consumers, businesses and governments need confidence to spend their own incomes or tap credit from a repaired financial system. Uchitelle then quoted Princeton University economist Alan Blinder: 'Deciding not to cut spending is the functional equivalent of spending more. Either one leads to more spending that you otherwise would have.' (Uchitelle, 2008)

Discussion: World Financial Crisis, October 2008

Firstly, note that the problem got worse, twice, not better after action was taken, leading us to believe that at the least, Type IV action errors were made. The first time action was taken, it was to limit, and then to disallow short-selling on financial institutions. This error of the 4th kind (action that should not have been taken) led to financial firms holding risky loans and investments in other banks, and at the same time being unable to hedge against devaluation of those assets. The SEC did not consider that the other primary financial hedge tool, the Chicago credit default swaps market (derived from the credit default insurance contracts), was at the same time becoming unstable (as AIG and other insurers began lacking the capital to back up the policies). With no reliable direct hedges available, financial firms decided they had to sell their un-hedged assets immediately. Unfortunately, with everyone needing to sell, there were almost no buyers and the finance industry asset values dropped faster than anyone predicted. The problem of (seemingly)

unethical short-selling had morphed into a massive devaluation of assets on the balance sheets of investment banks and mortgage institutions, and then a complete unwillingness of banks to make loans to each other. The life blood pressure of modern financial systems, the liquidity of assets, and the flow of cash dropped precariously, and then stalled.

The second time the situation worsened when action was taken was just after the stimulus package was enacted. Global stock markets dropped precipitously and nearly crashed entirely. Perhaps President Bush made it even worse on October 7 when he took action by announcing 'It's going to be awhile to restore confidence in the financial system.' For the financial markets, this was a self-fulfilling statement, with everyone realizing that they should not have confidence *now* (since it's going to take awhile). Furthermore, recall that the market stabilized and even began to recover during the days when the US Senate and House of Representatives rejected the bailout. That is, the problem dissipated *when no action was taken*, then immediately worsened when action was taken.

Secondly, note that the problem actually morphed into a new different problem, requiring more and qualitatively different resources. At the time of this writing (October 12, 2008), it is not at all clear what resources will be needed, or indeed what is the extent of the problem.

Thirdly, it is clear that the problem focused upon changed twice, and it is still not clear that the governments are even now working on the right problem. We think they are still working on the wrong problem.

Two years before this crisis, both Barack Obama and John McCain (the two presidential candidates at the time) had separately spoken about the sub-prime mortgage crisis, especially how it was affecting Fannie Mae and Freddie Mac, and yet nothing was done. Unfortunately, leadership in neither the US Senate nor the executive branch (the Bush administration) worked on this problem or acted on this problem. This may be understood as a $0, 1, 0_w$ path. It is also possible that this was a $1, 0_\beta, 0_w$ path. Perhaps the problem *was* worked on by leadership, but no significant relationship between Fannie Mae's and Freddie Mac's struggles and the greater financial system was identified, and furthermore, it was assumed that free financial market forces would take care of the problem, so there was no need to act. By the time the Bush administration recognized the problem it had already escalated into a crisis that was bringing down many Wall Street firms, and other investment banks around the world, causing a liquidity shortage crisis, requiring the government to step in for an estimated \$ 1 trillion.

If this was an error of non action on a problem that should have been acted upon, then it was a $1, 1, 0_w$ error of the 5th kind, with the outcome being a more severe problem of the same kind.

On the other hand, this may also have been other kinds of error: a $1, 0_\alpha, 1$ or a $0, 0_\alpha, 1$. That is, a Type I error of believing in a strong inverse relationship between the existing control systems and the problem, so that leaders thought just using the existing control systems more would make the problem less. Unfortunately, it may have been the case that the existing control systems were not adequate for the problem. For example, there is good reason to doubt that the VaR model (value at risk), used by the finance industry to assess appropriate portfolio risk, applies in extreme or complex situations (Rickards, 2008).

Case 2: Meltdown in the Tropics

On Tuesday evening, March 3, 1992, A manager, (we've changed his name to 'Mike'), was involved in an operations meltdown at Valentino's, a 120-seat 4-star restaurant at a resort in the Caribbean. He said it was 'his worst day of work, ever'.

Mike's goals for the evening were simple: smooth service, keeping the guests moving forward at the proper 1:45 minute pace per table, turning the tables over about 1.5 times. This would hopefully result in serving about 150 guests at the \$ 60 per person check average, yielding expected revenue of \$ 9000.

It was the last day of Mardi-Gras, the day of the grand parade. At 4:30 pm, two waiters and the cashier, all scheduled to begin at 3:30 pm, had not yet shown up. At a table in the back of the dining room, Mike remained unfazed. He and the chef had planned ahead for the possibility that some of the staff might skip work in favor of the carnival parade. The number of guest reservations was 100, well short of the usual. This meant that operations would be covered even with no-shows, and even if there was the typical good handful of walk-ins (no reservations). Days earlier, Mike had asked the hotel's front desk cashier to be available to cover the restaurant cashier's spot, just in case he needed him. The regular cashier had negotiated to come in for just two hours so she could be with her family. Mike had said yes to her because family is more valued in that country than a job. She would have simply been forced to skip work altogether and get fired. Mike figured two hours was a good compromise, since she could teach the front desk guy, then he could take over when she left. In the end, she was one of the 'no shows' anyway.

Mike said it didn't matter because the backup cashier had been able to come in an hour early and was already organizing his station. It looked like he knew his stuff. It seemed like the problem was solved. Scheduled employees not showing up could be a serious problem, so foresight on those matters is a good thing to have. With the backup cashier already there, and only 100 reservations, the missing servers and cook would barely be missed.

Neither Mike nor the chef nor any of the staff had any idea just how bad that evening would turn out to be. Mike's belief, that the problem was having no shows on the kitchen and the service staff, was wrong. Not only was he solving the wrong problem, he also wasn't solving that wrong one well. Despite acting properly in advance by over-scheduling and under-booking, he missed two critical factors. First, because of the carnival parade, a lot of other restaurants were closed. All that overflow was directed by the taxis to Valentino's, so there were going to be a huge number of walk-ins. He didn't tell the receptionist about his planning and he didn't say not to seat too many walk-ins. He just never saw it coming. Second, Mike was focusing on the wrong problem. He should have been focused on the critical expertise held by the cashier who did not show up, and worried that the replacement he'd arranged might not know what to do if things got busy.

At 6pm, early walk-in food sales were keeping the line cooks busy and the chef was forced to set up a work station for himself aiding the effort to get ready for the dinner rush. Five tables of walk-ins showed up at about 6:30 pm. Because the reservation book was only half full, and the main rush was scheduled to start around 7:15 pm, the receptionist seated everyone without a second thought. At that point everyone was working as hard and fast as they could.

Fast-forward to 8:25 pm. The manager had just been called to the restaurant ten minutes earlier, and had come quickly from his back office. At the building entrance impatient guests with reservations were lined up out the front door. The bar and restaurant entrance was jammed too. To Mike, it didn't make sense – the reservation system was supposed to take care of guest flow. It provided a regular, even flow in 15-minute cycles. When he asked the receptionist and the bartender 'what happened?' they said 'hopi-hopi walk-ins' and that the cashier was slow.

Upstairs the main dining room was full of irate customers, waiting to pay their bills. There were waiters and section captains looking panicked and lost. After kind of keeping up when things were slow, the back-up cashier had floundered, then panicked under the rush. The few guest checks that got to customers were wrong. To make things worse, he didn't tell anyone he was having any trouble until waiters starting asking for the first guest checks at about 7:45 pm. First wave guests couldn't pay and therefore couldn't leave. The main rush of guests was already waiting for those tables, many for 30 minutes or more. To make matters worse, those guests who wanted to hail a taxi to take them elsewhere found that there were no taxis. Everyone was at the parade.

The cashier had lost track of things under the flood of orders that came in when the rush started. When things were slow, from 6 to 7 pm, he'd been OK, slowly finding buttons and opening tables, adding orders to the system, and letting them print out in the kitchen. After seven o'clock, though, he quickly fell behind and then lost track of things. Nobody found out until he had panicked and told one of the floor captains at about eight o'clock.

He had no idea what items had been ordered or served. Even after realizing he was drowning, he had continued to attempt to use the cash register, hoping that somehow it would work itself out. When waiters learned that there was no written record of what people had ordered they decided to start asking the guests and hope for honesty. It was going to take a long time and the backup of guests had already created a log jam impossible to unravel.

The guests had long since started raising their voices and demanding service. One of the most difficult things about retail work is having clearly unhappy and damaged customers, and no idea what to do to make things right.

That is when Mike realized that not one person in the whole establishment knew how to run the cash register. Mike directed the cashier to stop trying to use the electronic cash register and to organize the receipts and billing by hand. Mike then distributed three-part order pads to the waiters (replacing

the two part forms they were using), so that they could drop off a copy of each order in the kitchen. It didn't help.

It was too late for solutions on how to run the cashier's station. The problem had become toxic and had morphed into a different one. The new problem was massive backup at all stations, initially caused by a clogged bottleneck at the cashier's station, but not solvable by unclogging that bottleneck. Now every station was a bottleneck. To get things flowing fast and move inventory forward out of each station to the next, it would require that guests eat faster. Unfortunately, that's not really a viable option.

Mike resigned himself to the fact that neither he nor anyone else knew what to do to stop or even control this building disaster. When people saw Mike give up, organization crumbled. The staff panicked and everyone started working only for themselves. At the end of the night, servers went home with a lot of undisclosed tips, Mike sat numbed and crestfallen, and the chef cried, never having been through such a thing. Some of the staff looked like they'd seen Dante's inferno itself. The little problem of predictable employee 'no show' had turned into an avalanche - it had been a full-scale operations meltdown.

In the days that followed, the accounting department calculated a 60 % shortfall on payments by the 80 guests they managed to serve that night. There were reservations for about 150, all of whom showed up. Two months later the manager was looking for another job.

Discussion: meltdown in the tropics

Mike made a Type III error right from the start and as he focused his attention on that, he ignored the importance of that hour or two of on the job training the backup cashier was supposed to receive from the main cashier, who did not show up. This was a 0, 1, 1 error. Mike correctly saw that there was a relationship between the carnival and no shows, and acted correctly by lowering the number of reservations and overstaffing for that reduced level of service. However, when the cashier did not show up, he added a Type I error, believing that the front desk cashier was a solid substitute for the everyday cashier. That hypothesis, assumed to be true, was not. He was now on a 0, 0_α, 1 decision path. The compounding of Type III error and Type I error, and correctly taking action, (because action certainly was needed), created a Type VI error, and the problem morphed into a complete operations meltdown. Introducing a bad cashier into an otherwise working-as-normal system combined in all kinds of ways to create chaos. Had the replacement cashier not been brought in, service staff would have worked manually from the start, and everyone would have known that things were going to move slowly. The bartender and the receptionist would have known that they were going manual, and that this would present a challenge. Therefore they would have turned away rather than seated many of those walk-ins.

Mike made at least one other vision error. He did not envision the tidal wave of customers who had gotten into taxis, headed out to dinner houses that turned out

to be closed, and ended up as walk-ins at the more costly Valentino's. With basic environmental scanning, he would have known that many of his competitors were going to be closed during the final day of Carnival. These unplanned for guests were promptly seated at tables not yet reserved for that time slot. With the backed-up cashier, operations could not move the early walk-ins and early reservations out of the late reserved slots. The restaurant, because of the massive influx of walk-in guests, was operating at full capacity, and people were still showing up, and would keep showing up en masse for a few hours.

CONCLUSION

There are six different kinds of decision error spanning three levels of decision. Type I and Type II error take place at a middle level of decision making when figuring out the forces and relationships involved in a problem. We call these kinds of errors 'correlation errors'. Type III error occurs at a more macro level, when deciding what the problems are and what problem to work on. We call this level of error 'vision error'. We then introduce Type IV and Type V errors (errors of the 4th and 5th kind) as 'action errors.' Action error can occur when deciding whether or not to act on a possible solution to a chosen problem. Type IV error is acting when action was uncalled for, and Type V error is not acting when action was called for. Finally, Type VI error (error of the 6th kind) is a compounding vision, correlation, and action error.

A decision maker goes through these three levels of decision: the vision decision, the hypothesis test decision, and the action decision. The first level is where either the right problem is identified and worked on, or a Type III error occurs. At the next level there are three possibilities. Either the evidence/data is correctly analyzed, or a Type I (α) or Type II (β) error is made. At the third level, where a decision about action must be made, there are four possibilities. Two of the possibilities are correct and two are in error. Correct action may take the form of acting when action is called for, or not acting when waiting or doing nothing is called for. The two action errors are the opposites of these.

All six kinds of error may have serious consequences, and error of the 6th kind is the most dangerous. Interactions among variables in complicated contexts, such as financial systems, business operations, political arenas, global climates, and so forth often exist in precarious balance and chaotic order. The introduction of even a single new force, or the withholding of an expected force, can lead to massive disorder, unforeseen outcomes, and a transformation of one problem into brand new and completely different problems.

We have also detailed out a binomial decision tree that tracks the 24 decision sequence possibilities implied by our three-level system and summarized the implications of each pattern. Using this decision tree, and applying 'what if' prior probabilities, one can derive resulting probabilities for each of the outcomes. When we apply 'good decision maker' prior probabilities, we find that that even a good decision maker will probably have about a 70 % success rate.

APPENDIX I

SUMMARY OF DECISION COMBINATIONS

<i>Decision Path</i>	<i>Error Type</i>	<i>Description</i>
1, 1, 1 _a :	No error.	Right Problem, causes understood, take action, action solves problem.
1, 1, 0 _a :	IV	Right Problem, causes understood, unnecessary action taken, problem worsens.
1, 1, 1 _w :	No error.	Right Problem, right causes, do not act, problem solves itself.
1, 1, 0 _w :	V	Right Problem, right causes, do not act, problem worsens.
1, 0 _α , 1 _a :	I	Right Problem, evidence wrong, there was no correlation, take action on mistaken correlation. Can make problem worse or make problem morph by introducing new forces.
1, 0 _α , 1 _w :	I	Do damage done. No action is taken on mistaken correlation.
1, 0 _α , 0 _a :	VI	By introducing new forces into a group of previously uncorrelated forces, new correlations and unexpected outcomes occur.
1, 0 _α , 0 _w :	I & V	Double negative avoids damage. Mistaken inaction avoids damage of α error and wasted resources.
1, 0 _β , 1 _a :	N/A.	Action is not a rational path if no correlation evidence is found.
1, 0 _β , 1 _w :	II	Right Problem, evidence was wrong, there was a correlation, do not act. Problem likely festers and gets worse.
1, 0 _β , 0 _a :	II & IV	Results in No Error. Mistaken action solves problem.
1, 0 _β , 0 _w :	N/A.	Mistakenly waiting not a rational path if no correlation evidence is found.
0, 1, 1 _a	III	Action solves wrong problem. May help contain/check 'true' problem if action is on a related problem. May be irrelevant to 'true' problem.
0,1, 0 _a	VI	Inappropriate action on wrong problem introduces new correlates and new worse problems are created.
0,1, 1 _w	III	Systems and processes already in place solve the 'wrong' problem. 'True' problem festers.

(Continued)

$0, 1, 0_w$	III & V	Resources are not wasted working on the wrong problem and no confounding correlates are introduced.
$0, 0_\alpha, 1_a$	VI	Evidence was wrong, shouldn't have acted. Action creates new unexpected correlates and outcomes.
$0, 0_\alpha, 1_w$	N/A	Not a rational possibility.
$0, 0_\alpha, 0_a$	III & I & IV	Results in Type VI. Mistaken action on assumed relationship that does not in fact exist, working on the wrong problem. New potential correlates are needlessly introduced. Both problems may get worse and/or morph.
$0, 0_\alpha, 0_w$	III	Results in Type III. Double negative limits damage. Mistaken inaction avoids damage of α error and wasted resources, initial problem festers.
$0, 0_\beta, 1_a$	N/A	N/A. Action is not a rational path if no correlation evidence is found.
$0, 0_\beta, 1_w$	III & II	Results in serious Type V. Working on wrong problem, evidence was wrong, should have acted. Both problems fester.
$0, 0_\beta, 0_a$		Mistaken Action solves the wrong problem. Error of 3rd kind.
$0, 0_\beta, 0_w$		N/A. Not a rational path.

NOTES

1. When saying sufficient we make no claims to the decision being optimal in outcome or optimal in process. It is our perspective that many fine decisions are suboptimal, as managers satisfice in order to move forward. Sufficient resolution also does not mean that the decision maker went through all of the steps normative decision-making models would describe, i.e. problem identification, diagnosis, idea generation, criteria sieve, alternative selection, and implementation. Competent decision making also does not necessarily mean following an optimal search pattern. For example Simon's satisficing model follows a different search pattern than does Einhorn's Elimination by Aspects model and both wind up with a decision, often different and often suboptimal, but not necessarily. A successful decision and successful action simply means that the decision and the action work in terms of the problem.

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