Risk Determination in Highly Interactive Environments: How to Avoid the Titanic Factor in Your Project—A White Paper

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As project managers, we all know how important it is to establish the risks our project may face. We are also aware of the need to quantify the risks we have identified, but how much time do we spend calculating how one risk occurrence may affect another risk probability? "Two risks might seem independent, but the probability of one occurring might change if the other materializes; the response to one risk might alter the consequences of or the probabilities of materialization of the other; or, the response to one risk might limit the project's ability to respond to another." In other words, how do intra-project risks interact and how can we take those interactions into special consideration?

The Sinking of the Titanic — Multiple-Risk Materialization and Interactions

Let's look at a famous example of how multiple-risk materializations led to one of the world's best-known disasters, the sinking of the RMS Titanic on 15 April 1912. In this case, almost every conceivable known unknown (risks) that could occur did occur, with a couple unknown unknowns as well.

Known Unknowns — Design of the Ship as a Risk Factor

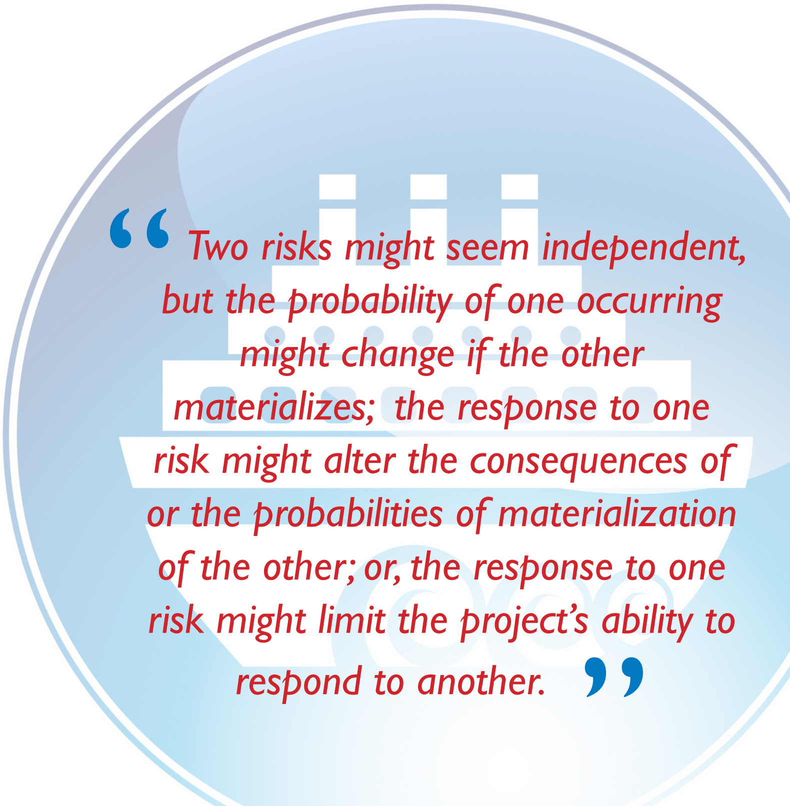
As the largest steamship built up to that time, the RMS Titanic was conceived to be state-of-the-art. It had "watertight" bulkheads and was believed to be unsinkable, based on an erroneous interpretation by White Star Line's Managing Director, Mr. J. Bruce Ismay's comment that she (Titanic) was "nearly unsinkable."

The Watertight Bulkheads

The design of the bulkheads was not truly watertight. The tops of the bulkheads only extended a few feet above the waterline. As six of the sixteen watertight compartments were breached and began flooding, the weight of the water in the bow pulled the ship under until the bulkheads overtopped.

The Rudder

The design for the rudder was considered adequate for use on the open seas; however, it was 30% to 40% undersized for the tight maneuvers that would have been required that fateful night. Tugboats performed ship handling in port and so a larger rudder was not required.



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Engine Configuration

While reversible steam piston engines powered the outer two propellers, the central propeller had a steam turbine as its power source. This engine could not be reversed and was stopped during the run up to the iceberg. This stopped the water flow past the rudder and became a critical factor in its effectiveness.

Further Known Unknowns — Ship Procedures as Risk Factors

Several procedural issues contributed to the collision and were revealed after the fact. Let's examine them in more detail:

Passing Iceberg Reports to the Bridge

Titanic was making her crossing in mid-April at the height of the March–May iceberg season in the North Atlantic. Iceberg reports from the SS Amerika and Mesaba were not passed on to the bridge. The reports showed large icebergs south of the Titanic's path. Captain Edward Smith did have some reports from previous days and did alter the course to approximately 10 miles south, but this distance was not enough.

Speed

Although it was widely reported at the time that Mr. J. Bruce Ismay ordered the captain to run at full speed in order to achieve a record crossing, his later testimony indicated that Titanic was traveling at 22.5 knots, 0.5 knot below her top speed, which was still too fast for the amount of ice in the area.

Wireless Operators Priorities

The wireless had been inoperative all day and having just been restored, wireless operator, Jack Phillips, was busy sending out the day's messages from passengers. SS Californian radio operator, Cyril Evans attempted to warn Titanic of a large ice field ahead at 11:00 p.m. but was told by Phillips to, "Shut up! Shut up! I am busy! I am working Cape Race!"(the wireless relay station), and so another critical iceberg warning failed to reach Titanic's captain.

Ill-Equipped Lookouts

Three teams of two lookouts who were posted in the crow's nests did not have binoculars. Combine this fact with the calm sea causing no observable breakers against the iceberg, no moon, and a thoroughly melted surface of the iceberg that reflected the dark night sky, the deadly iceberg was next to impossible to see at any distance that would have helped in this situation.

The Captain's Orders Immediately Prior to the Collision

Upon receiving the report of, "Iceberg, Right ahead!" from the lookout, Frederick Fleet, Sixth Officer James Moody informed First Officer William Murdoch of the call. Murdoch immediately ordered hard a'starboard (full left turn) and full astern on the engines. This was an attempt to port around the iceberg by turning the ship's bow to point left of the iceberg, allowing it to pass, and then Murdoch ordered hard a'port to swing the stern clear. Since the central engine was a steam turbine, it had to be stopped instead of reversed, leaving an all too small rudder with only the water flow from Titanic's forward speed, which was being reduced by the full astern order. The huge ship reacted too slowly to miss the iceberg with the first third of her hull.

Unknown Unknowns — Material Failures

There were two other factors that contributed greatly to the sinking of the Titanic, which were not known at the time but were discovered much later. We will not consider these in our later analysis but will mention them here as a reminder that all projects have unknown unknowns for which we need to build in safety factors to compensate for.

Sulphur in the Hull Steel

In 1991, a hull fragment was retrieved and thoroughly tested; the conclusion was that a high oxygen and sulphur content in the steel led to brittle fracture in the cold North Atlantic waters (28° F). Charpy impact tests revealed almost no ductility. The steel simply broke without bending first. Had modern steels been available, the hull would not have had such long ruptures and it is possible the pumps could have at least delayed Titanic's plunge long enough for an effective rescue to have been mounted.

Hull Seams Split Open as Iron Rivets Burst

Adding to the hull breaches were hull plate seams that opened due to iron rivet heads popping off, which, again, was due to cold fracture brittleness. The strain from the deformation of the hull plates stretched rivet holes, popped rivet heads off, and burst caulking in the seams, adding to the inward water migration.

At the time of the sinking, metallurgy had not yet reached the point of studying the low temperature physical properties of metals; hence, a mitigation strategy for these risks was not considered.

Risk Interactions in the Sinking of the Titanic

Had any one of the known unknowns not occurred, the

Titanic might have had a long career ferrying passengers across the Atlantic. The interactions that compounded are legend.

Double Interactions

Iceberg Density versus Speed of the Ship

With so much ice in the area, traveling at 97% of her top speed was critical to Titanic's ability to avoid the iceberg. These two risk factors could also be considered with the rudder size to create a triple interaction.

Rudder Size versus Engine Configuration

With a small rudder and a non-reversible central engine, the ship simply could not react quickly enough to avoid an iceberg that was, "Right ahead." You could include speed to create a triple interaction. Slower would have been better.

Watertight Bulkheads versus Port Around Orders

By sideswiping the iceberg, approximately 300 feet of Titanic's 900-foot hull were severely damaged. Some comments indicated, to the effect that it might have been better to hit the iceberg head-on, possibly damaging fewer watertight compartments. She might have remained afloat longer, so the rescue attempt would have been more effective.

Iceberg Reports versus Wireless Priorities

Procedurally, ignoring reports of icebergs was a critical factor in the sinking. Titanic was sailing at the height of the North Atlantic's iceberg "season," which runs from March through May. If there ever was a more critical time for the captain to be aware of the presence of icebergs, it was right then. Although Captain Smith had received some earlier reports, several crucial ones were not forwarded to him. This includes the most critical report from the SS Californian shortly before the collision; wireless operator Phillips' priorities were the passengers' messages instead of the safety of his ship.

Triple Interactions

Iceberg Detectability versus Speed versus Lookout Equipment

On a moonless night, with waters deadly calm and no binoculars for the lookouts, Titanic's speed was excessive. The iceberg was nearly undetectable in these conditions. If the lookouts had had binoculars or the ship had been going slower, more time from the initial sighting to the collision might have allowed the evasive orders to be more effective, thereby reducing the damage and loss of lives.

Watertight Bulkheads versus Speed versus Port Around Orders

What really dragged the Titanic to her watery grave was the complete filling of her bow's watertight compartments, which pulled the bow of the ship completely under, lifting the stern up to 45 degrees out of the water until the stresses broke her backbone. The watertight bulkheads only extended a few feet above the waterline and were overtopped one by one. Furthermore, without the bulkheads, the water would have been more evenly distributed along her length, keeping the ship horizontal longer.

The speed of travel and the port around orders, combined with the inadequate bulkheads, were significant interactions. By adding the rudder size to the known risk factors, we can create a quadruple interaction.

How Should Risk Interactions be Determined?

First, we should look at the simple double interactions. Where can two of the risk factors combine to create an even greater risk? You can express this in your risk matrix quite simply by adding lines. as shown in the Design of Experiments exercise for "A X B," as shown in Table 1.

You can even add rows showing the triple, quadruple, or higher orders of interactions. This will work fine for smaller projects with few risks. Risk mitigation strategies can then be formulated should any of the combinations occur, just as those that occur with single risks.

Risk	Unlikely	Somewhat Likely	Likely	Very Likely	Certain
A X B					X
A				X	
B X C				X	
B		X			
C	X				

Consequence

Failure Probability

Table 1: Simple risk matrix with three risks and two interactions.

Morphological Analysis

How about large-scale projects that have many risk factors? Here, a morphological analysis can be useful. "Fritz Zwicky pioneered the development of morphological analysis (MA) as a method for investigating the totality of relationships contained in multi-dimensional, usually non-quantifiable problem complexes." It is a computer-aided analysis "…for structuring complex policy and planning issues, developing scenario and strategy…"

Morphological analysis was created to examine an alternative to mathematical and causal modeling of systems to predict future outcomes within a range of possible outcomes. It relies on the expert judgment of the team and internal consistency. Originally, morphological analysis was used to predict social/political reactions and policy needs. This arena is the ultimate in non-quantifiability; however, although many of our risk factors are not directly quantifiable, our expert judgment can get us quite close and this technique can then be very useful.

The Morphological Approach

Morphological analysis examines, "…the total set of possible relationships…contained in a given problem complex." The five iterative steps of the process for our use in project risk analysis are:

1. State the problem concisely — What are the project's goals?
2. All of the known unknowns must be localized — Risk determination.
3. Construct the morphological box, a multi-dimensional matrix containing all the potential risks — See Figure 1.
4. Scrutinize all the solutions at each intersection, with respect to the project's goals.
5. Optimal solutions are selected and practically applied to the project.

This gives us 27 potential interactions (3^3 – three non-interactions – e.g., R1 X R1 X R1) to examine in this simple three-risk model. "The point is, to examine all of the configurations in the field, in order to establish which of them are possible, viable, practical…and which are not." If we are truly looking at a matrix of only three risks, this can be done without complex computer modeling. But there is a point at which the amount of data can be overwhelming. Six risk factors create 2304 possible configurations, and a ten-factor analysis exceeds 300,000 configurations.

The total number of configurations to be examined can be reduced by a cross-consistency assessment by eliminating pairs of conditions that are mutually inconsistent or contradictory. For example: if you choose a red car, the car cannot also be blue or green. Depending on what the risk factors are for the project under examination, certain combinations cannot happen together. This assessment is reliant on the application of expert judgment in a logical and empirical fashion only. "We must first discover what we judge as possible, before we make judgments about what is desirable."

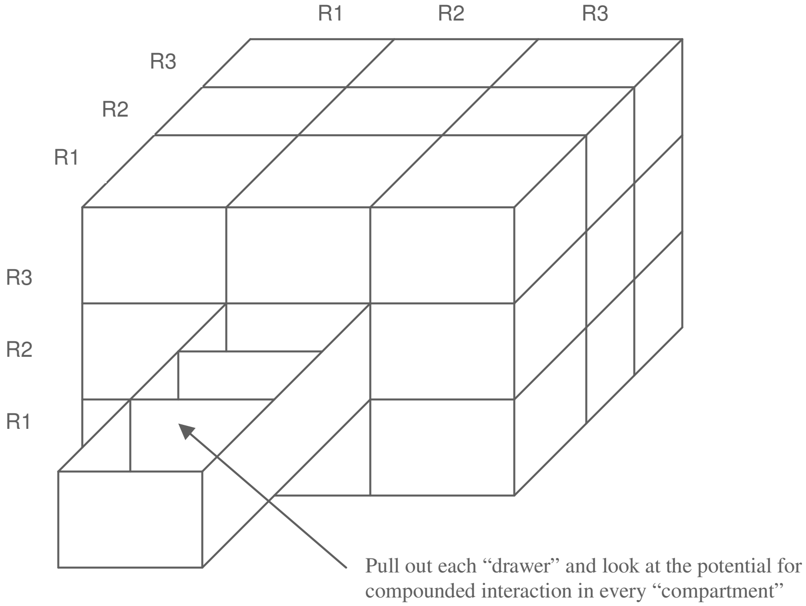
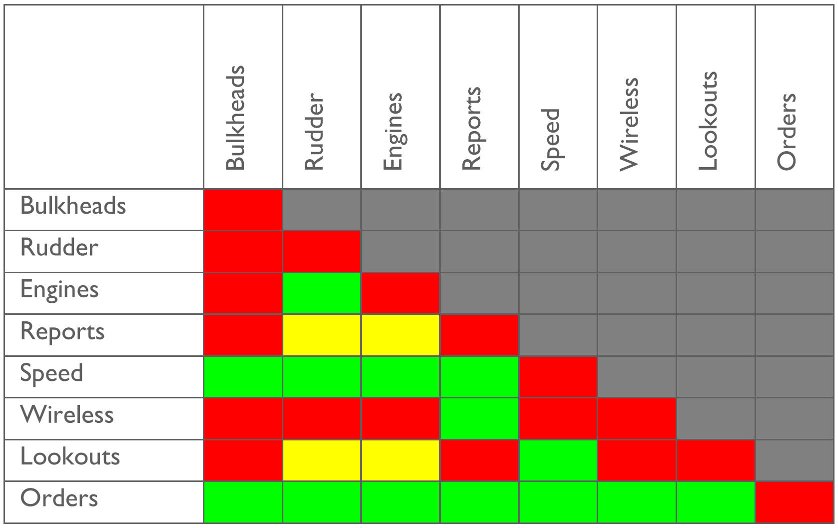


Figure 1: A Three-Parameter Zwicky Box.



	Bulkheads	Rudder	Engines	Reports	Speed	Wireless	Lookouts	Orders
Bulkheads	🟥	▨	▨	▨	▨	▨	▨	▨
Rudder	🟥	🟥	▨	▨	▨	▨	▨	▨
Engines	🟥	🟩	🟥	▨	▨	▨	▨	▨
Reports	🟥	🟨	🟨	🟥	▨	▨	▨	▨
Speed	🟩	🟩	🟩	🟩	🟥	▨	▨	▨
Wireless	🟥	🟥	🟥	🟩	🟥	🟥	▨	▨
Lookouts	🟥	🟨	🟨	🟥	🟩	🟥	🟥	▨
Orders	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟥

Table 2: Titanic Cross-Consistency Matrix.

By constructing a cross-consistency matrix for the previously identified risk factors on the Titanic, we can see how this works (see Table 2).

Configurations that are contradictory or have no relationship are colored red, weak relationship configurations are colored yellow, and those with a strong relationship are colored green. For example: The small rudder is strongly related to the engine configuration of a central turbine (a reversible engine may have enabled a larger rudder to turn the ship more quickly) but only weakly related to the lookouts not having binoculars (if the ship could steer more quickly, the ability to detect the iceberg at a greater distance may have helped.)

Thus, out of a possible 8 risk factors, 36 interactions are reduced to 14, with another 4 weak relationships. We can now examine the strong relationships between possible configurations in the morphological box for specific solutions to complex combinations.

For larger risk matrices, MA/Casper was originally developed for the Swedish Defense Research Agency and is not available commercially. However, there are other computer programs available, which can be downloaded for free; a Google search for, "morphological analysis" will turn them up and you will have to determine their applicability to your projects individually.

How Much Risk Management is Enough?

If we attempt to determine each and every risk a project may face and all of their interactions, we risk "analysis paralysis," the point at which we accomplish nothing of practical value because we have not uncovered all conceivable risk. "Before starting, you should recognize that you cannot do a perfect job, and anything approaching perfection will become expensive." A project manager cannot fall into this trap, or managing risks will be all that he or she will have time to do. Preston Smith likens it to insurance. "You can buy high levels of insurance to provide a great deal of protection, but this will become expensive."

Instead, it might be useful to gather 80% of the unknowns, leave placeholders for as yet undiscovered risks or interactions, and proceed. Adding risks to the risk matrix as they come up and massaging them into the assessment as the project progresses will make them more realistic. This is similar to the rolling wave planning used in creating schedules when not all activities are fully planned.

In the end, the project manager has the responsibility of managing project risks adequately. Used widely, morphological analysis can be a great addition to the project manager's toolbox and help keep your project from experiencing the "Titanic Factor."

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