

Introduction to Portfolio Risk Analysis ¹

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Projects can be part of a larger portfolio in which projects are strategically selected and managed. Project portfolios can share common risks, mitigation and response plans, and resources. Conversely, these same projects exposure to these same risks can vary and have different scores for the same risks. One of the key goals of project portfolio management is to align and prioritize projects based upon the organization’s objectives. Part of this process takes place using an enterprise risk register that contains all the risks the organization faces. Risks from this risk register can be assigned to different projects, and in turn, to each project’s tasks and resources.

Why Perform Portfolio Risk Analysis

Climbing Mount Everest, whose peak sits at 8,848 metres (29,029 ft) above sea level, is one of the riskiest projects in the world: by March 2012 Everest had been climbed 5,656 times with 223 deaths. This works out to a fatality rate of 4 percent (NASA World Observatory 2016).

Outside of conflict zones, it is perhaps one of the most risk endeavors you could imagine doing during peace time. Add to this, that this is for the most part a non-commercial venture (some expeditions do have sponsors), and these climbers are often actually paying tens of thousands of dollars to be part of an expedition that has a 4% of having the worst possible outcome for them.



Figure 1. Everest's north face from the Tibetan plateau. Photo by Joe Hastings

Let’s take a look what each climbing expedition involves. Everest has a number of climbing routes; the two main ones include the southeast ridge from Nepal and the north ridge from Tibet (Everest History 2016). Expeditions for the southeast ridge ascent usually fly from Katmandu to the town of Lukla (2,860 m). Before the expedition begins, climbers need to procure all equipment and supplies,

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hire yaks and human porters, and other logistical preparations. The climbers start the next leg of their journey, the trek up to Base Camp at an altitude of 5,380 m (17,700 ft). This trek usually takes six to eight days, which provides a suitable period to begin the adaptation to the extreme altitude. This acclimatization process continues for the next couple of days at base camp as the expedition prepares the upcoming ascent. During this period time, Sherpas and other experienced climbers set up ropes and ladders in the Khumbu Icefall. The climb now takes place in a series of short ascents from one camp up to another. First they will climb to Base Camp I at 6,065 meters (19,900 ft).

From there, the climbers make their way up to Camp II or Advanced Base Camp at 6,500 m (21,300 ft). Next is Camp III located on a small ledge at 7,470 m (24,500 ft). The penultimate step is to climb to Camp IV, where the climbers need to pass the Geneva Spur, an anvil shaped rib of rock, which needs to be ascended using ropes. The culmination of the ascent is the push from Camp IV to the summit that usually takes 10-12 hours. This final stage is broken down into several mini climbs. First, the climbers need to reach "The Balcony", which is a small platform at 8,400 m (27,600 ft).

Once they have reached the Balcony, they continue on up to their next goal, the South Summit, a small dome of ice at 8,750 m (28,700 ft). After this, climbers must perform the "Cornice traverse". Any misstep on this traverse could end up with a fatal plunge of 2,400 m (7,900 ft). If they complete the traverse successfully, they face one last obstacle. Close to the summit there is another a 12 m (39 ft) rock wall. Once this has been cleared, the climbers have a relatively clear path to the summit of Mt. Everest. Unfortunately for our hardy adventurers, they face the same steps with the same challenges on their return route. Nothing comes easy and if we can see the conquering Everest is not just a single long activity, or project, but really encompasses a project portfolio that can last several years if you take into account the projects involved in preparation. Each project within the portfolio involves different objectives and resources and needs to be managed separately: the success of the attempt at the summit of Mt. Everest depends on how successfully the leaders manage their project portfolio.

Any project within a portfolio has a number of risks; some of them are shared with other projects, but others are specific to individual projects. In an Everest expedition, a list of critical risks include:

- Frost bite and cold exposure: Climbers must spend a significant period of time within the "dead zone". The region above 8,000 m where extreme cold means that any exposed body parts are at risk of frost bite in a very short period of time
- Falls: Because of the extreme low temperature, the snow is characteristically extremely hard and difficult to traverse, chance of injury or death are greatly increased.
- Hypoxia or altitude sickness: The atmospheric pressure at the top of Everest is one third that found at sea level; as a result, low oxygen levels are required and oxygen tanks and masks are the norm.
- Avalanches: While they can occur at any altitude, in this region they can be especially devastating as the ability of the climbers to react to or recover from avalanche is greatly diminished. Rescue efforts are extremely difficult. In fact, on April 25, 2015 a number of people died at Base camp due to avalanche caused by the Nepal earthquake.

All these risks not only affect safety, but also duration, cost, and success rates of each project and therefore the portfolio. For example, if there is a problem with the transportation of supplies to the base camp, this could delay or potentially cause the cancellation or postponement of the expedition. Because we like movies, we can recall a 1992 movie “K2”, about the ascent of K2, the second highest peak in the world. In one scene, the Sherpas (porters) refuse to go forward placing the future of the expedition in doubt. While this makes for good movie drama, it is a scene that has happened many times in Himalayan expeditions.

Let’s see how we can manage risks in a project portfolio containing a number of projects that share the same risk register.

Project Portfolio Hierarchy

Project portfolios have the same structure as projects: just like a project can have summary activities and sub activities, a portfolio can have summary projects and sub projects (Virine and Trumper 2017). Below is an example for a project portfolio hierarchy and Gantt chart for the Everest Climbing portfolio (Figure 2). In case you are wondering, this is a realistic schedule (Berg International Adventures 2016), so if you want to try to climb to Everest, you may use it (though we have left out the preparation stages for simplicity). Just perform your risk analysis first.

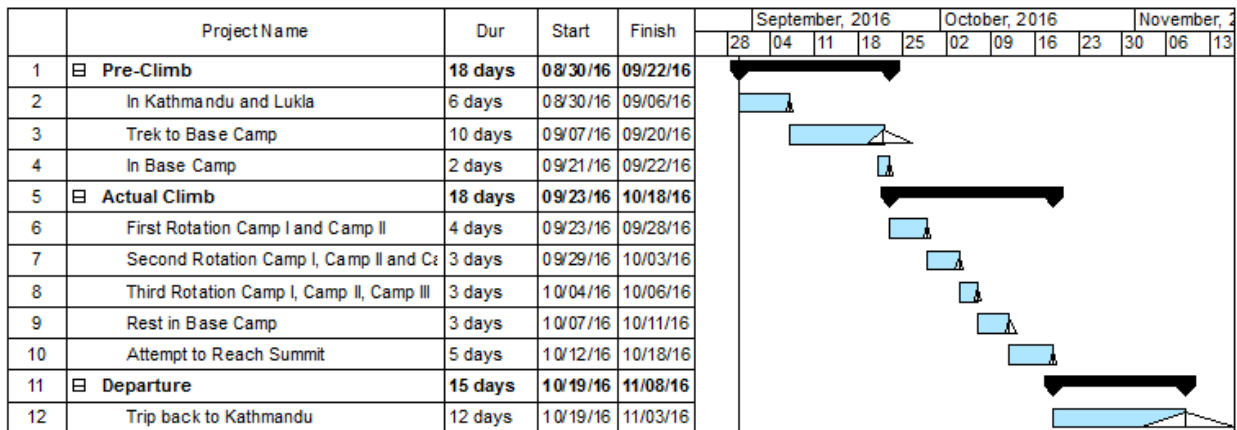


Figure 2. Everest Climbing Project Portfolio

Each project within a portfolio has tasks, resources, and risks assigned to the tasks and resources. Tasks may have uncertainties expressed as statistical distribution of duration, cost and other parameters. We can perform Monte Carlo project risk analysis of each project in the portfolio. The results are shown on Figure 2 as triangles: they represent the low, base and high durations of each project. If you are using Portfolio management software, usually you can open each project schedule from within the portfolio view. With detailed project views, it is possible to view the statistical distributions of project duration, cost, and other parameters for each project.

Projects within a portfolio can have cross dependencies which can be modeled as predecessor or successor type links. Common resources such as people and materials can also assigned to different projects within a portfolio.

Prioritization of Projects

People have a tendency to compare and prioritize all sorts of things regardless of how important or difficult it might be, we automatically make judgements: it is an inherent aspect of human psychology. For example, if we listen to a variety of classical musicians, we inevitably make judgments about which musician is superior. Most of us find it quite enjoyable to sit around and discuss and debate these sorts of subjective preferences. However, in many cases such as classical music, it really takes some expertise to distinguish between the qualities of performances of professional musicians. In other cases, we do this intuitively such as the case in a fire, most of us would automatically prioritize invalids and children for evacuation as they are the most vulnerable (Figure 3)? In project management, we also prioritize different project sand risks, but often doing it intuitively without analysis, so while often the results are good, this can lead to inconsistencies. As we have already learned how to prioritize project risks, we will now see how we can extend this process to the actual projects within a portfolio.

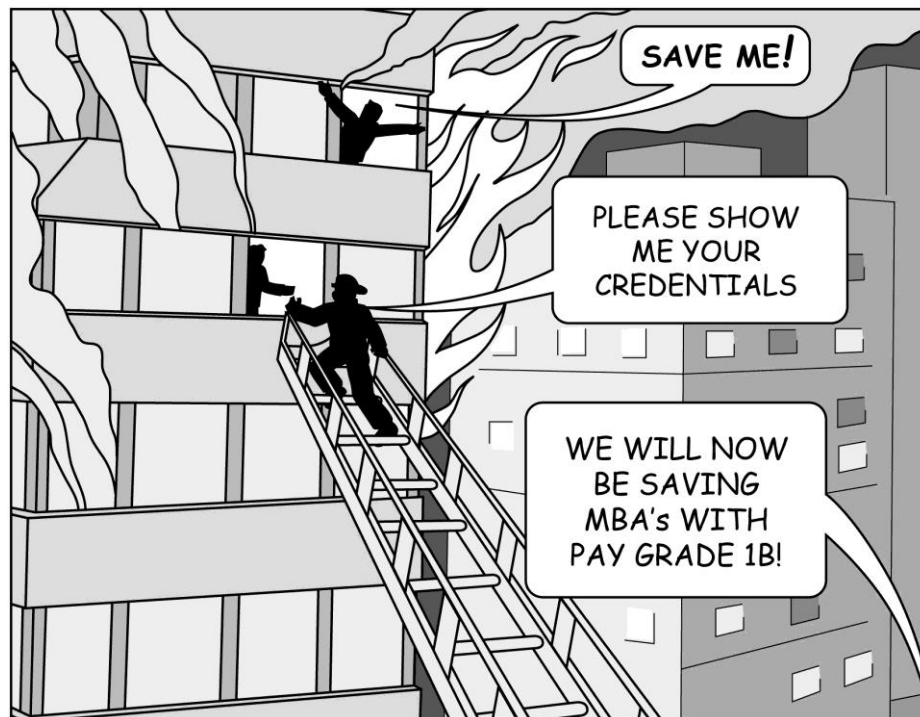


Figure 3. Prioritization of saving people during the fire.

Why should we prioritize projects? Here are three important reasons:

1. Projects may require additional resources, which require immediate attention.
2. Project priority can be used to calculate the risk score for the project.

3. Risk ranking in an enterprise risk register depends on the priority of project to which this risk is assigned. Projects with higher priority will be given a higher weighting when calculating the risk impact.

There different approaches on how to prioritize projects. The simplest method is to simply assign different priorities to the project. What are the most important projects for Everest Climbing portfolio? It depends on what do you want to achieve, or your portfolio objective. For example, if your primary goal is to reach the summit, all projects are important with exception of “Descent back to base camp”. However, if the primary goal is to ensure you arrive at Base camp, and if conditions allow, you may attempt the summit, all projects before “Actual Climb” have higher priority. If this was the case, you might assign “Pre-Climb” projects a priority of 100% and the “Actual Climb” priorities 80%.

For more complex portfolios a more sophisticated approach is required. We can use the *analytic hierarchy process* to prioritize risk categories using pair wise comparison. We can also use this process to prioritize projects. At its most basic level, you can ask which project is more important: “Descent to Base camp” or “Trek to Base Camp”. You can perform this for each pair of projects in portfolio and calculate the relative priorities.

Another process you can use for complex portfolios is Multiple-criteria decision-making (MCDM) or multiple-criteria decision analysis (MCDA) (Ishizaka and Nemery, 2013). For example, if you assemble an airplane or construct a skyscraper, these may require aligning projects with different objectives, and for each objective, a project may have its own priorities. Examples of these objectives might be:

- complete all projects on time and on budget
- retain personnel
- improve organizations capabilities
- develop new technology that can be applied to future projects
- provide high return on investment (ROI)

With these objectives defined, we can then prioritize the objectives. Finally, we can rank projects on how well they satisfy certain objectives. This will allow us to calculate overall ranking of projects within a portfolio.

Project Risk Score

Project risk score is a number or an indicator that helps to rank project risks. Project risk scores can be calculated separately for duration, cost, and other risk categories, such as safety, security, quality, etc. Calculating risk scores based on the results of qualitative and quantitative analysis is possible, but can be misleading. We recommend using three separate risk scores:

- For project duration
- For project cost

- For other non-schedule related risk categories

There are different ways to calculate project risk score. It is possible to do it based on statistical parameters, such as mean, standard deviation, range, P10 or P90 of statistical distribution. Here is an example of project duration score calculation formula:

$$\text{Score} = \frac{\text{Duration Mean} + \text{Standard Deviation of Duration}}{\text{Duration Original}}$$

Where:

Duration mean = mean project duration as a result of analysis

Duration original = Original (baseline) project duration with no risks and uncertainties.

Using the formula above:

- If project does not have duration risks, the Duration score will be equal 1.
- If the Duration risk score is >1, the project has threats related to duration.
- If the Duration risk score is <1, the project has opportunities related to duration.

Risk scores for non-schedule or cost risks are calculated the following manner:

1. For each project and category there is an array for risk results. For example, if there are two risks “Quality of installation” (probability 50%, impact 30%) and “Quality of manufacturing” (probability 20%, impact 40%), the array for the quality category may appear as shown in Table 15.1:

Monte Carlo Iteration	Cumulative risk impact
1	0
2	30% + 40% = 70%
3	30%
4	0
5	40%
6	0
7	0
8	30%
9	30%
10	30%

Table 1. Cumulative risk impact using a Monte Carlo simulation

2. The mean of this array is calculated and multiplied by the weight assigned to each non-schedule risk category
3. The sum of values from Step 2 is calculated for each project for all risk categories; this number is absolute non-schedule risk score for the particular project.
4. Absolute non-schedule risk scores for all projects are normalized in such a way that:
 - if a project does not have any risks, the score will = 1
 - if a project has opportunities, the score will be < 1
 - if a project has threats, the score will be > 1.

In this way the risk scores for non-schedule risks will be compatible with risk scores for duration and cost.

Enterprise Risk Register

All risks for the portfolio are saved in an *Enterprise risk register*. Risks from an enterprise risks register can be shared across different projects in a portfolio. They can be assigned to projects and to individual tasks or resources. Essentially, each project will have its own “view” or “representation” of an enterprise risk register: some risks from enterprise risk register may not be assigned to a particular project and therefore will not be shown in project’s risk register. For example, the risk “Problem with yaks” would not be assigned to the project risk register of “Attempt to Reach Summit”, but would be assign to the project risk register of “Trek to Base Camp”. However, regardless of their individual assignments to specific projects all risks will be saved in the enterprise risk register. Here is the interesting phenomenon: the ranking of a risk in the enterprise register may be different than for a particular project. “Problem with Yaks” will have a high score for the project “Trek to Base Camp”, but at the portfolio level it will be quite low (Figure 4). This discrepancy occurs because of two reasons:

1. Cumulative impact of risk “Problem with Yaks” for the portfolio will be low.
2. Project “Trek to Base Camp” to which this risk is assigned will have a lower priority.

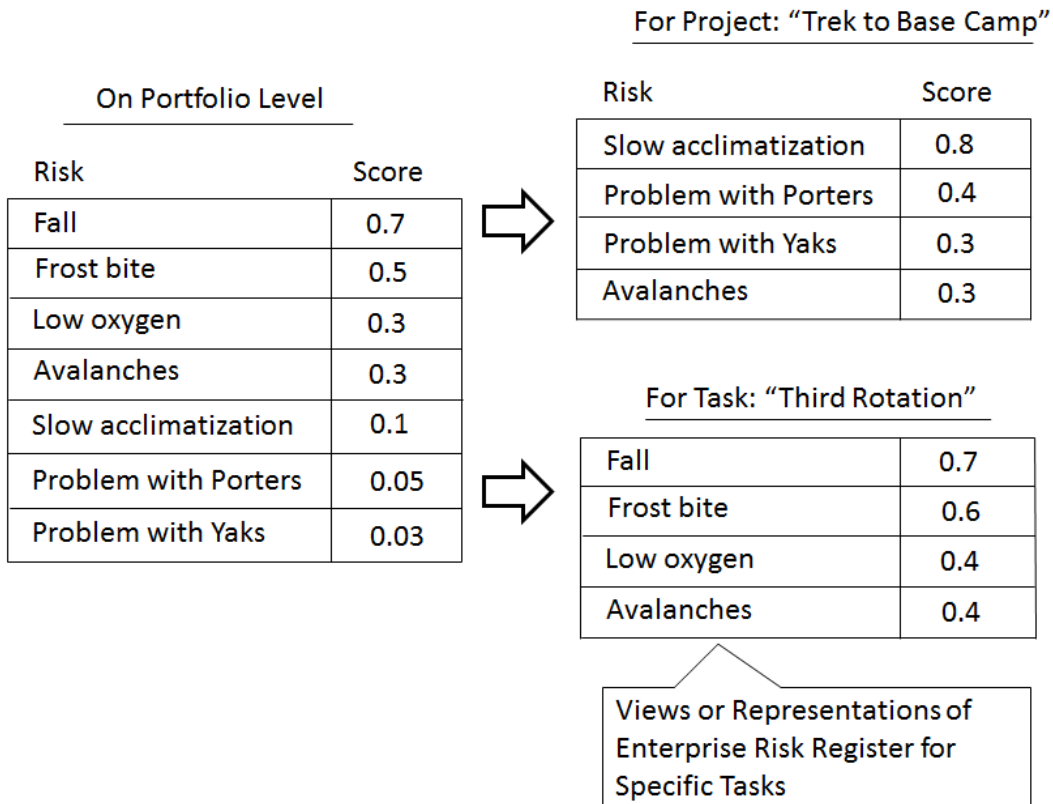


Figure 4 Portfolio and project level registers for specific risks

Therefore, the Enterprise risk register at the upper (portfolio) level will look different than a risk register for particular project. Please note, that each summary project within a project hierarchy may also have its own “view” or “representation” of the Enterprise risk register, which again may have different risk rankings than the higher level risk register.

Here is how you can use an enterprise risk register:

1. Identify and enter risks to the enterprise risk register. For example, four main risks, related to the climbing Everest: fall, frost bites, low oxygen, and avalanches.
2. Open projects and assign risks to appropriate tasks for particular project. When you assign risks, you enter probability, impact categories (duration, cost, quality, safety, etc.), and impact values (increase duration on 20%). You can do this for each project.
3. Perform Monte Carlo simulations for all updated projects. Risk registers for individual projects are generated and risks are ranked.
4. Save the project. At this point. Project priorities and risk impacts will be used to calculate the risk score of each project. The enterprise risk register for all portfolios is updated including risk rankings.

In addition to risks, enterprise risk register includes mitigation and response plans which also can be shared between different projects

Risk Visibility and Risk Approval Rules

When a new risk is added to a project is subject to two properties that we can approval and visibility. Approval indicates the risk has been approved by management and can be included as part of the portfolio risk register. Visibility indicates where in the portfolio this risk can be assigned: projects, summary projects, or the portfolio. Why is this required? Let us assume that we have a risk “Budgetary Problems” for our Everest expedition. It is not something that we want to share with all of the people in your team, it may cause some team members to leave if they are worried about getting paid or being stranded penniless in Katmandu. Different risks will have different visibility, for example “Low Quality Carabiners affect only those projects related to climbing with ropes, so we will manage them at the project or summary project level, rather than the portfolio level.

Each project portfolio usually has *Risk visibility rules* (Figure 5). These rules define how risk will be visible, when it is just entered to the portfolio. For example, when risk is first added to the register, visibility settings can portfolio level, for all summary projects, immediate summary project, or current project.

Portfolio Level (all projects)		All Summary Projects	
Project	Visible	Project	Visible
Project 1	<input checked="" type="checkbox"/>	Project 1	<input type="checkbox"/>
Summary Project 1	<input checked="" type="checkbox"/>	Summary Project 1	<input checked="" type="checkbox"/>
Project 1	<input checked="" type="checkbox"/>	Project 1	<input checked="" type="checkbox"/>
Summary Project 2	<input checked="" type="checkbox"/>	Summary Project 2	<input checked="" type="checkbox"/>
Summary Project 3	<input checked="" type="checkbox"/>	Summary Project 3	<input checked="" type="checkbox"/>
Project 2	<input checked="" type="checkbox"/>	Project 2	<input checked="" type="checkbox"/>
Only Immediate Summary Project		Current Project	
Project	Visible	Project	Visible
Project 1	<input type="checkbox"/>	Project 1	<input type="checkbox"/>
Summary Project 1	<input type="checkbox"/>	Summary Project 1	<input type="checkbox"/>
Project 1	<input type="checkbox"/>	Project 1	<input type="checkbox"/>
Summary Project 2	<input type="checkbox"/>	Summary Project 2	<input type="checkbox"/>
Summary Project 3	<input checked="" type="checkbox"/>	Summary Project 3	<input type="checkbox"/>
Project 2	<input checked="" type="checkbox"/>	Project 2	<input checked="" type="checkbox"/>

Figure 5. Setting Up Risk Visibility and Approval Rules

Enterprise risk management software usually has different roles and permissions for users. Some users will be administrators and have complete access to the system, others will have management roles such as being part of the risk committee, and others will be members of specific projects and will have access only to specific project and/or risks. When a new risk is entered into the system, it may be visible to administrators and some managers, but remain invisible to the majority of users

depending on visibility and approval status. Once entered, a risk status can change depending on the review by the risk committee. For example, “Low Quality Climbing Carabiners”, was originally identified by a member of a specific project, but after review by the Risk Committee, its visibility has been extended to all climbing projects.

In addition, risk visibility and approval rules can be extended to mitigation and response plans. For example, if we the response plan for the risk “Fall between Base Camp IV and summit” involves summoning a helicopter, the person who enters this response plan may be an expert in helicopter rescues or not. If not, the approval process may change the visibility of this response plan to someone with more expertise in this area.

Risk Bubble Chart

One portfolio objectives could be related to minimizing risk. In general, we find organizations are very amenable to the idea of maximizing returns with as little risk as possible, just look at how financial portfolios are managed. Let’s say that you have two opportunities: invest in a Zambian based start-up “Eletrocow ”, which promises to produce artificial milk extremely inexpensively using fusion power artificial cows, or a 300 year old US based company “Shovel and Axe” which as the name suggests produces shovels and axes. The opportunities are on the one hand the Zambian company has a small probability of providing huge return on investment and give you huge return. On the other hand, “Shovel and Axe” has a high probability of providing a small and steady return. If you have a high risk tolerance, you may choose a future as a dairy mogul, if not, your future may be less exciting, but in a good way. When managing project portfolios, it is important to ensure that you have your risk balance aligned with your portfolio risk tolerance.

The Risk vs. Duration/Cost chart (Figure 6) shows the relative risk associated with project versus project duration or total project cost. The horizontal axis is a measure of risk, the vertical axis is either duration or cost. Each bubble represents a project and the size of the bubble represent the project cost/duration and risk. Risk can be expressed as:

- Project standard deviation of task duration or cost
- Maximum or minimum values
- Ranges: the difference between maximum and minimum values
- Certain Percentiles
- Project risk scores

In a well-balanced portfolio, different projects will have similar levels of relative risk. However, if the relative risk associated with a project is higher than similar projects, the project should be flagged for additional analysis. Alternatively, if project has less relative risk, it may represent an opportunity where additional cost or schedule risk could be transferred to it to mitigate higher risk projects in your portfolio.

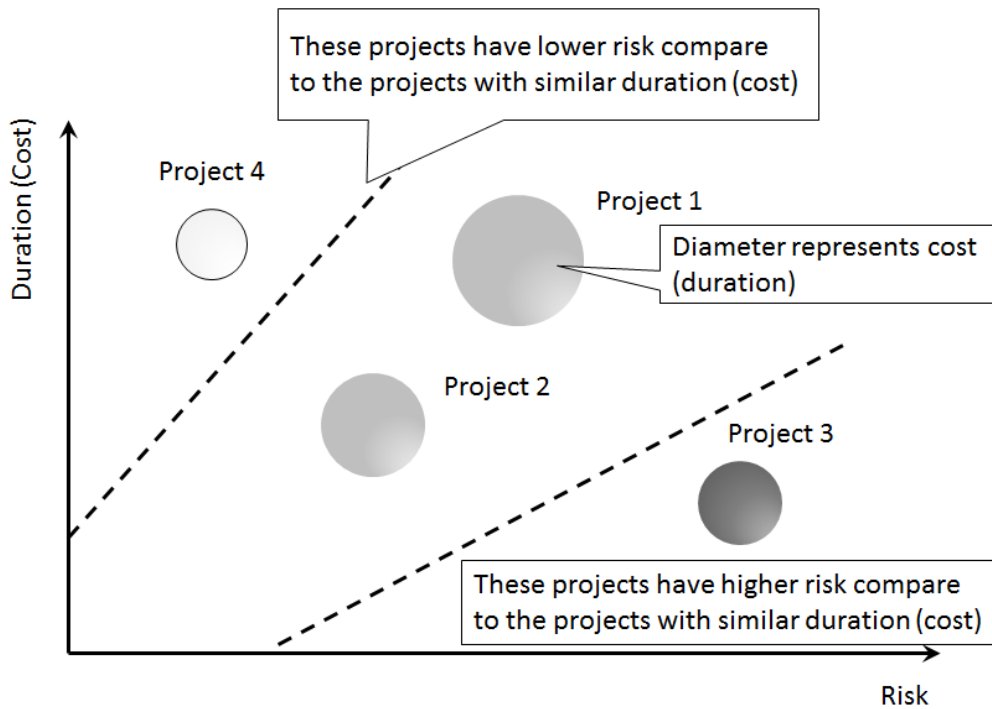


Figure 6. Risk vs. Duration/Cost bubble chart.

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