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Safety oriented bubble diagrams in project risk management

Keywords

bubble diagrams, project risk management, safety

Abstract

In project risk management many firms use bubble diagrams to get a graphical presentation of a project's most uncertain attributes. The bubble diagrams and procedures used to put attributes into these diagrams are seen to provide a rational framework for managing risks. In this paper we review and discuss the use of these diagrams and procedures. Special attention is given to the way safety is treated. We show that the standard use of bubble diagrams is not adequate for identification and follow up critical activities that affect safety. The main problem is that the present structure means that the uncertainty is not properly taken into account. In this paper a reformulated bubble diagram is suggested that better reflects safety related uncertainties.
The offshore oil and gas industry is the starting point, but the discussion is to large extent general.

1. Introduction

Project risk management is a systematic process of identifying, analyzing, and responding to project risk [9].

The project risk management process is in the literature described in terms of phases, which are decomposed in a variety of ways, see for example [5] and [6]. One of the phases in the project risk management process is risk assessment, which involves the entire process of analysing and evaluating risks.

In the risk assessment phase of project risk management, a method that involves bubble diagrams is often used to get an overview of a project's most critical attributes at the point of time. The basis for the bubble diagrams is that the risks are considered through three dimensions: 1) consequence, 2) probability and 3) manageability. First, the risks are analysed by an evaluation of these dimensions, then the criticality of the risks is evaluated based on the results from the analyses, and finally the results are presented in a bubble diagram.

Risks included in the bubble diagram are often related to technological considerations. In the offshore oil and gas industry for example, risks included in the bubble diagram are to a large extent related to technological considerations such as reservoir conditions (reservoir volume, reservoir compositions, sand production, changes in well stream, etc.), drilling conditions (technology, maintenance, etc.), construction condition (technology, weight, time, etc.) and operational conditions (regularity, potential for modifications, etc.) [11].

Risks related to safety, that are mainly concerned with low-probability and large consequences, are normally not considered in project risk management. Such risks are considered in safety management. Safety management is strongly related to project risk management, but while the project risk management considers all risks regarding the project outcome, i.e. both events with negative and positive consequences, safety management addresses only the accident risks. So far bubble diagrams have not been used for accident risks.

In this paper we review and discuss the use of these diagrams and procedures in a project management context. To what extent could these diagrams be used to identify and follow up activities that affect safety? What type of adjustments are required to make the diagrams suitable for this type of application?

To be able to respond on these issues, we need to clarify what risk is. A common definition is that risk expresses the combination of consequences and probabilities [7]. In this paper we adopt a generalisation of this definition which state that risk is the combination of consequences C and associated uncertainties U, i.e. (C, U), in line with [1] and [4].

The point is that probability is a tool to express uncertainty. It is however not a perfect tool, and we should not restrict risk to the probabilistic world. The probabilities are conditional on a specific background knowledge, and they could produce poor predictions. Surprises relative to the assigned probabilities may occur, and by just addressing probabilities such surprises may be overlooked [1], [2] and [8].

Taleb makes a similar conclusion using the black swan logic [12]. The inability to predict outliers (black swans) implies the inability to predict the course of history. An outlier lies outside the realm of regular expectations, because nothing in the past can convincingly point at its occurrence. The standard tools for measuring uncertainties are not able to predict these black swans. We find also similar ideas underpinning approaches such as the risk governance framework [10] and the risk framework used by the UK Cabinet Office [4].

Traditionally, the uncertainties are expressed through probabilities in the bubble diagrams. Following our perspective on risk, we suggest a modified bubble diagram which reflects uncertainties beyond the probabilities.

The paper is organised as follows. First, in Section 2, we give a review of the bubble diagrams in project risk management. Then in Section 3 we discuss the appropriateness of using the bubble diagrams to identify and follow up activities that affect safety. In Section 4 we give suggestions of an improved bubble diagram. Finally, in Section 5 we draw some conclusions.

2. Review of the bubble diagrams used in project risk management

The bubble diagrams in project risk management are used to get a graphical presentation of different risks that are considered important. Information about the different risks is given through three dimensions: consequence, probability and manageability.

The bubble diagram is based on a consequence-probability characterisation as shown in Figure 1. The manageability is visualised through the bubble sizes. The criticality of the risks is decided through an evaluation of these three dimensions, and is represented by a colour. The classification of the risks in the bubble diagram is just a snapshot of the situation and is continuously updated.

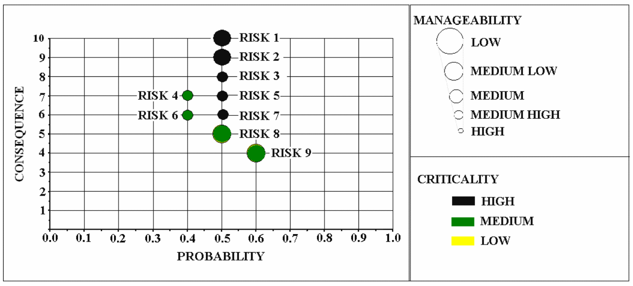

Figure 1. Graphical presentation of different risks in a bubble diagram

The classification of risks into the bubble diagram is carried out on the basis of an understanding of the different dimensions as described in the following:

Manageability:

The potential for reducing risk and obtain desirable outcomes. The 'potential' is considered as the capability the firm has to reduce risk and obtain desirable outcomes seen in relation to other concerns, in particular cost. We say that the manageability is high if it is considered feasible to implement measures over time which can reduce risk and give increased confidence in obtaining desirable outcomes. Similarly we understand a low manageability.

Probability:

The probability included in the diagram is either:

- an expression of the uncertainty associated with an event A

or

- an expression that specific consequences C will take place. Analysts typically treat 'specific consequences' as consequences worse than the assigned expected value EC.

An example of a risk included in the bubble diagram where the probability is within the first mentioned category is "ship collision next year". A ship collision will next year either occur or not - it is an event - and the probability included in the diagram is then an expression of the uncertainty associated with that event.

An example of a risk where the probability is within the latter category is "production cost". The "production cost" is not an event but a random variable, and the probability included in the diagram is then an expression of the likelihood associated with specific consequences.

Following the common practice, the probability included in the diagram for "production cost" is the probability that the production cost exceeds the assigned expected cost EC, i.e. P(C>EC).

Consequence (Expected negative impact):

The expected negative impact included in the diagram is either:

- the expected loss given an event A

or

- the expected loss given that specific consequences C will take place. It is common by the analysts to treat 'specific consequences' as consequences worse than the assigned expected value.

"Ship collision next year" is as mentioned before an event in this logic, and the consequence of this risk is then within the first mentioned category.
The consequence for "production cost" is related to the latter category. Following the common practice, the consequence included in the diagram for "production cost" is then the expected loss when losses worse than the assigned expected loss occurs, E[C | C>EC].
In the bubble diagrams the expected loss for risks is expressed through a consequence category (for example a number from 1 to 10). Different companies use different categories, and the meaning of the consequence categories are different.

The bubble diagram is closely related to a risk matrix. In the bubble diagram there will be a unique classification of the risk since attention is given to expected consequences. For "ship collision next year" the risk will be classified in the bubble diagram as the point (P(A), E[C|A]). This way of classifying risks can also be adopted for a risk matrix, but it is also common to use consequence categories in risk matrices. For example, if a ship collision occurs we may consider the consequence categories C_1 (0 fatalities), C_2 (1-5 fatalities), C_3 (6-20 fatalities) and C_4 (more than 20 fatalities). The risk could then be classified in the risk matrix as shown in *Figure 2.*

3. Discussion of the bubble diagrams in project risk management

To evaluate the project risks, focus must be placed on the most critical factors. In the bubble diagrams these are risk and manageability, where risk comprises consequences and probabilities. The risk is described by a prediction C* (expected consequence) of the consequences C and probability P, i.e. (C*, P). This way of describing risk means that the uncertainty is not properly taken into account as pointed out in the

		Consequences			
Probability/frequency		0 fatalities	1-5 fatalities	6-20 fatalities	More than 20 fatalities
	Prediction of more than 10 events over 1 year	✸			
	Prediction of 1-10 events over 1 year		✸		
	10-50% probability of one event over 1 year				
	1-10% probability of one event over 1 year			✸	
	< 1% probability of one event over 1 year				✸

✸ $P(C_i \mid A)$: Probability/frequency for consequence C_i if the undesirable event A occurs

Figure 2. Example of a risk matrix

introduction section. The ideas will be clarified through two examples.

Gas leakages in process plants

Consider the risk related to gas leakages in a process plant. To describe this risk an assignment is made for the probability that a gas leakage occurs during a specific period of time, and for the expected consequences given a gas leakage. Given the background information a leakage probability of 10% is assigned, and the expected consequence is assessed to be within consequence category 2.
Let us assume that the probability for a leakage to occur is based on two databases, which give completely different information about the frequency for gas leakages in process plants. Obviously, the assigned probability could lead to poor predictions of the number of leakages.
In addition to this, the consequences if a gas leakage occurs could be very different. In most situations the losses will be negligible, since ignition and explosion of the gas normally will not occur. But if an explosion occurs the losses could be rather extreme. The expected consequence will not properly take into account this potential for huge consequences, but it is

an important part of the risk and should be reflected when the risk is described.
In this example there are considerable uncertainties in underlying phenomena and processes and the standard approach presented above would not be able to reveal this important aspect of risk.

Offshore diving activities

Consider the risk, seen through the eyes of a risk analyst in the 1970s, related to future health problems for divers working on offshore petroleum projects in this period of time. An assignment is to be made for the probability that a diver would experience health problems (properly defined) during the coming 30 years due to the diving activities. Let us assume that an assignment of 1% is made. This number is based on the available knowledge at that time. There are not strong indications that the divers will experience health problems. However, we know today, that these probabilities led to poor predictions. Many divers have experienced severe health problems [3]. By restricting risk to the probability assignments alone, we see that aspects of uncertainty and risk are hidden. There is a lack of understanding about the underlying phenomena, but the probability assignments alone are not able to fully describe this status.

4. Suggestion of an improved bubble diagram

We suggest a modified bubble diagram to better reflect the uncertainties. See *Figure 3*. An uncertainty dimension is added in the diagram. We may for example use three different uncertainty levels; high, medium and low. In the diagram we visualise the uncertainty level by a letter inside the bubble for the specific risk. The letters L, M and H are used to visualise whether the uncertainty for a risk is assessed to be within the Low, Medium or High uncertainty level, respectively. In *Figure 3* we see that the uncertainty level for “ship collision next year” is assessed to be high.

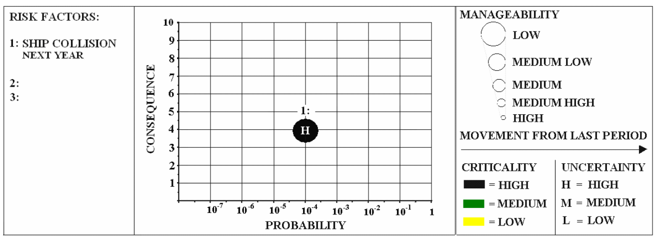

Figure 3. Uncertainty dimension incorporated in the bubble diagram

In the diagram several risks will be classified, and therefore we will refer to the different risks with a unique number as shown in the above figure. To better identify and follow up activities that affect safety a logarithmic scale is used on the probability axis.
We recommend classifying the risks into the diagram in the same way as for the traditional bubble diagram. That means that the position for the different risks will be exactly the same in the two diagrams. Incorporation of the uncertainty dimension can lead to that the classification of the criticality for the different risks can be modified. We may start the criticality classification by first rank the risks according to the three standard dimensions consequence, probability and manageability. Then we may adjust these up or down in case the uncertainties are considered high or low. In the two examples discussed in the previous section, the uncertainties are considered high and hence both risks should be considered reclassified, for example by increasing the criticality score one category up.

5. Conclusion

In the bubble diagrams risk is described by a prediction of the consequences (expected consequence) and the probability. In this paper we argue that such a description of risk is not broad enough, since the uncertainty is not properly taken into account. The assignments are conditioned on a number of assumptions and suppositions, and are not expressing objective results. The main component of risk should be uncertainty and not probability. Uncertainties are often hidden in probabilities and expected values, and restricting attention to these quantities could camouflage factors that could produce surprising outcomes.
The information about risks visualised in the traditional bubble diagrams could be useful in project management. The diagrams summarize important features of the knowledge and lack of knowledge concerning operations and other activities, and give in this way a basis for making rational decisions. A reformulation of the bubble diagram where the uncertainty dimension is included is suggested to further improve this decision basis. By extending the risk picture to also cover uncertainties beyond the probabilities and expected values, we believe that the bubble diagrams would be better able to capture “surprises” – which we all know happen from time to time.

Acknowledgement

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References

[1] Aven, T. (2007). A unified framework for risk and vulnerability analysis and management covering both safety and security. *Reliability Engineering and System Safety* 92: 745-754.

[2] Aven, T. (2008). A semi-quantitative approach to risk analysis, as an alternative to QRAs. *Reliability Engineering and System Safety*, to appear.

[3] Aven, T. & Vinnem, J. E. (2007). *Risk management, with applications from the offshore oil and gas industry*. Springer Verlag.

[4] Cabinet Office. (2002). *Risk: improving government's capability to handle risk and uncertainty*. Strategy unit report. UK.

[5] Chapman, C. & Ward, S. (1997). *Project risk management: Processes, techniques and insights*. Second edition. Chichester: Wiley.

[6] Cooper, D., Grey, S., Raymond, G. & Walker, P. (2005). *Project risk management guidelines – Managing risk in large projects and complex procurements*. Chichester: Wiley.

[7] ISO. (2002). *Risk management vocabulary*. ISO/IEC Guide 73.

[8] Iversen, R. S. (2007). *Uncertainty management for the operational phase* (in Norwegian). Master thesis. University of Stavanger.

[9] Project Management Institute. (2004). *A guide to the project management body of knowledge*. Third edition. US.

[10] Renn, O. (2005). Risk Governance. White paper no. 1. International Risk Governance Council. Geneva.

[11] Surdal, J. (2002). *Uncertainty management in Statoil: Risk and opportunity management*. Presentation for the Norwegian research program in HSE: Decision support tools.

[12] Taleb, N. N. (2007). *The Black Swan: The impact of the highly improbable.* London: Penguin.