J Soc Sci, 34(1): 9-15 (2013)
PRINT: ISSN 0971-8923 ONLINE: ISSN 2456-6756
DOI: 10.31901/24566756.2013/34.01.02

Quantifying Human Error via Operational Risk Analysis: Ecological Disposition

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KEYWORDS Quantitative Risk Analysis. Likelihood of Occurrence of Risk. Risk Modeling. Impact of Occurrence of Risk

ABSTRACT The objective of the paper was to demonstrate the methods and process of Quantitative Risk Analysis (QRA) through likelihood of occurrence of risk. This case study stratified the sampled respondents of hundred (100) risk analysts. The analysis of likelihood of occurrence of risk by logistic regression and percentages were used to investigate whether there was a significant difference or not between groups (analyst) in respect of QRA. The Hosmer and Lemeshow test was non-significant with a chi-square (X^2 =8.181; p = 0.300), which indicated that there was a good model fit, since the data did not significantly deviate from the model. The study concluded that to derive an overall likelihood rating the following governing factors must be considered: (1) threat-source motivation and capability (2) nature of the vulnerability (3) existence and effectiveness of current controls (methods and process). It is recommended however that steps in measuring likelihood of risk should determine the adverse impact of risks.

INTRODUCTION

Past studies have raised concerns about the complexity of risk modelling (Nicholas 2004; McNeil et al. 2005). The researchers firstly attributed the complexity to the type of risk modelling, thus either quantitative (mathematical/statistical models) and or qualitative (subjective/judgemental models) (Nicholas 2004; McNeil et al. 2005). Secondly, there has been a long standing argument about what constitutes or defines risk (Nicholas and Steyn 2008; Standard and Poor 2006). Ibid's assertion, commensurate with that of Nicholas's (2004), who cautioned what is considered as risk or risk modelling. The reason being that an appropriate modelling is considered only when there exists precise and concise definition of risk taking into account in its context. Thus, the debate about a definitive constituent of risk has frequently added to the complexity of modelling risk, suggesting that there is always difference in the specific definition of risk and thus model of risk.

For the purpose of this study and to limit the varying definitions of risk to suit the study; *risk* means the probability (likelihood and impact) of an adverse outcome measures of risk, which may be generated based on observed statistical qualities of risk.

Two of the best known statistical qualities of measures of risk are variance or standard deviation. Variance or standard is a statistical measure of the dispersion around an expected value (say mean) whereby a larger variance or standard deviation indicates greater dispersion (Markowitz 1957). Although, there are numerous potential measures of risk; for instance in the field of financial mathematics and statistical risk analysis, in higher education, it is not clear how to derive an overall likelihood rating that indicates the probability that a potential risk may be exercised within the construct of an associated threat environment. This as some authors (Stoney 2007; King III Report 2009) requested calls for further research.

The discussion of measures of risk is divided into likelihood of occurrence of risk and impact of occurrence of risk.

Generically, Nicholas (2004: 313) identified two distinct features of risk which point to the fact that risk addresses; (1) the likelihood that some problematical event would occur and (2) the impact of the event if it does occur. The risk, Nicholas (2004) claims is a joint function of likelihood and impact of risk variables representing the risk consequence. This mathematically is expressed as:

Risk consequence= f(likelihood, impact)

But first, how does the aforementioned constitute risk in higher education institution (HEI)? As noted from Nicholas (2004) in previous sections, HEI can manage risk by reducing the like-

lihood and the consequences of harmful events happening. To manage risk, analyst considers what constitutes risk variable. The various variables under consideration as risk are; (1) target of 3rd stream income (2) pass rates for all students (3) throughput targets met in the institution (4) allocation of infrastructure (5) teaching staff with masters and or doctorates qualification and (6) teaching staff involved in research. This also resonates with the objective of the study within which it intends to demonstrate how quantitative risk analysis is modelled in the study with respect to an HEI.

Objective of Research

The main objective of the paper was to demonstrate the methods and process of QRA through likelihood of occurrence of risk. The premise underlying the entire research was that risk is quantifiable via a mathematical relationship shown below;

Risk consequence = (likelihood of occurrence of risk **X** *impact of occurrence of risk)*

This suggests that risk is a function of two elements. This first part of the study uses this analogy to demonstrate the quantification of risk.

Research Hypothesis

Ho: There would not be significant difference between risk analyst of a University using the quantitative risk analysis.

Ha: There would be significant difference between risk analyst of a University using the quantitative risk analysis.

RESEARCH METHODOLOGY

The analysis of likelihood of occurrence of risk by percentages and logistic regression was done to investigate whether there is a significant difference or not between groups in respect of components in the questionnaire used. In order to examine the questionnaire of groups; frequency and percentage were calculated. Descriptive analysis (Cohen et al. 2003; Hedeker 2003; Hamilton 2003) was used. A correlation coefficient based on Spearman-Brown formula was 0.91. This was done in order to test inter-rater reliability of the scores obtained from the experts who assessed the questionnaires in groups.

Method

Sequential explanatory strategy, which is one of the mixed method strategies, was used in this study (Hamilton 2003). Thus, the essence was to use qualitative results to assist in explaining and interpreting the findings of a primarily quantitative study.

Participants

Participants were 100 risk analysts of a University who were either managers and or directors of schools or units and were simple randomly selected. Since the participants were selected from two different campuses (termed group 1 and 2), the following comparative procedures was administered; firstly, independent sample t-test was used among the two groups to determine if there was any statistically significant difference between the two groups in terms of responses. The distribution suggested that mean scores of group 1; (M=259.93, SD = 6.70) and that of group 2; (M= 259.77; SD = 10.55) differed. However, findings of the t-test [t (46) = 0.06, p>0.05] was not statistically significant, suggesting that group1 and 2 were similar in respect of their response scores.

Secondly, the researchers ensured that risk management course content (RMCC) was clear to both groups, thus to determine comparable levels of understanding of risk practices of the two groups in the University. In this direction, its content (RMCC) validity was identified by experts and it was developed by considering the results of item analyses of the pilot study. The reliability coefficient of the pretest was 0.89. The t-test, which was done with the means of the pretest scores [t (46) = 0.56, p>0.05] was not statistically significant. Suggesting that group 1 was not different in respect of understanding the RMCC. The next section addressed the results and discussion of studies.

RESULTS

The first category of variable under investigation is shown in Table 1, thus - what likelihood of occurrence of risk is associated with below target of 3rd stream income? Table 1 represents the variables that indicate preliminary risk quantification. This was preliminary in the sense that part of the result was used in the mathemat-

ical model (cf. Bayesian analysis). Table 1 shows that over two-thirds (81.3%) of respondents asserted that the likelihood of occurrence of risk associated with below target of 3rd stream income was likely not to be met, once in an academic year.

This may seem plausible as compared to responses such as not meeting the target quarterly, monthly and even weekly.

Table 1: Likelihood of occurrence of risk is associated with below target of 3rd stream income

Responses	*Frequency*	*Percentage (%)*
Rare- Remote possibility (once every 3 years or more)	2	3.1
Unlikely- Could happen but rare (typically once a year)	52	81.3
Possible -Could happen occasionally (on average quarterly)	4	6.3
Likely - Could happen often (on average once a month or more)	4	6.3
Almost Certain- Could happen frequently (once a week or more)	2	3.1
Total	64	100.0

To support the 3rd stream income, the University often depends on the fees recovered from the students. Noting from the above indexes and coupled with the interviews sessions, it was noted by Lin (a respondent) that : "...the university's recovery rate of students fees as at the academic year 2008/2009 was in the neighbourhood of 90% per academic year."

That amounted to the money (fees) recovered from students per academic year. But as an interviewee (Xolani) added; "...it takes long period to recover it (sometimes in a new academic year).

Literature (Mishra and El-Osta 2002; Standard and Poor 2006) advocated that in such instances, the policy of the university should be adhered to. In relation to this research, the policy of the university required that it recovers funding from students between the months of August or September, but instead, the debt was recovered around March of each following year as aforementioned. This put the university at a risk on the cash-flow management and its capacity to operate. When the question of percentage of third stream income was raised, respondents noted that this depended on how the university defined it. This was because every university has its own definition. The definition for the university as Goba, an interviewee captured was "... money that comes to the university for which council can exercise its discretion and has control over." By that it would be the institution's interest income, the surplus generated from projects or funded projects the excess that flows, the investment in assets that come as a result of project funding.

But as the interviewees explained, the university's sources of third stream income were generated from variety of sources. In the year 2008, ascertained during the interview, the university benefited either in the form of bursaries and or interest, investment in assets, acquisition of assets to the extent of about R35 million (about $5m as of June, 2009), which was about 8% to 9% of the university's income base. This to a large extent marks a good start for the university in terms of generating 3rd stream income. One respondent (Lin) commented that:

That is not too bad but in other institutions it is much higher. That is about around R30million ($4m), some of which is used to fund a project, to fund bursary students….

Lin maintained that his comment is a good indicator in terms of generating 3rd stream income, as the HEFCE (2001) noted, funders would not give you (institution) money, if they feel an institution would not mange it or would not add value to it.

DISCUSSION

With regards to the likelihood of not meeting the target in pass rates for students in the institution, a similar view (70.3%), as happening once within a year was revealed. Whereas the view of pass rates not being met in weekly, monthly and on average three-years as seen in Table 2 was low, it was relatively popular (17.2%) that pass rates may not be met on average quarterly. The vast difference between codes such as pass rates not being met at least once a year and that of quarterly may be attributable to the fact that the academic year ends within one year which is a cumulative of semesters (quarters of a year).

Table 2: Likelihood of occurrence of risk is associated with below pass rates

Responses	*Frequency*	*Percentage (%)*
Rare- Remote possibility (once every 3 years or more)	1	1.6
Unlikely- Could happen but rare (typically once a year)	45	70.3
Possible -Could happen occasionally (on average quarterly)	11	17.2
Likely - Could happen often (on average once a month or more)	4	6.3
Almost Certain- Could happen frequently (once a week or more)	3	3.1
Total	64	100.0

Similarly, majority (65.6%) supported the notion that once a year there was the likelihood of not meeting percentage throughput targets (third variable). The view was also popular in terms of percentage throughput target not met quarterly (21.9%).

Regarding the trend noted above, the same could not be said about the likelihood of risk associated with not meeting the target of allocation of infrastructure in Table 3. Over one-half (65.6%) were of the view that there was a likelihood of not meeting the target set forth by the institution under one academic year. In this composite percentage (65.6%), while a one- fourth (25%) of the total responses thought quarterly there was the likelihood of occurrence of risk associated with not meeting the targets set by the university, another one-fourth agreed that there was a likelihood of risk associated with not meeting the target on average once a week. Less than one-fourth (15.6%) viewed that the risk of this happening was nearly within monthly basis as seen in Table 3.

In terms of this variable, it may appear worrying for an analyst, once the composite value less than one academic year is as huge as seen below. The reason, being notably that a business cycle of the University was normally within one academic year. Which suggest that if the risk as noted above was that high, then the likelihood of not meeting the objectives of the University within that academic year would ultimately be high. This may tie well with the previous tables where most responses attributed the likelihood of risk occurrence to this (variable) and other variables mentioned above as not being met less than one academic year.

Table 3: The likelihood of occurrence of risk associated with allocation of infrastructure

Responses	*Frequency*	*Percentage (%)*
Unlikely- Could happen but rare (typically once a year)	22	34.4
Possible -Could happen occasionally (on average quarterly)	16	25.0
Likely - Could happen often (on average once a month or more)	10	15.6
Almost Certain- Could happen frequently (once a week or more)	16	25.0
Total	64	100.0

Logistic Regression Analysis

Two logistic regression models were used to examine and to predict the correct classification of the risk elements. The independent variables used for these analyses were obtained from the background questionnaires of risks elements administered to the analyst. Note that these questionnaires were identical in the two groups. The first logistic model used variables that dealt with risk associated with below target in pass rates (RPR), while the second model addressed differences that existed in the risk associated with allocation of infrastructure. Finally, to reduce the risk of inflating the alpha estimates, all variables that were used in the previous two models were entered into one last model. After this model was run, only the independent variable that was significant.

Risk Associated with Below Target in Pass Rates (RPR)

The first logistic regression that was performed included a set of 4 independent variables

that examined if the two groups of risk analyst differed in risk associated with below target in pass rates (RPR). The overall chi-square test for the logistic model was significant ($\chi^2 = 114.00$; $p < 0.05$) which indicated that there was difference between the two groups on the two RPR. In addition, the Hosmer and Lemeshow test was non-significant with a chi-square ($\chi^2 = 8.181$; $p = 0.300$), which indicated that there was a good model fit since the data did not significantly deviate from the model. In terms of the variance that was explained by this set of variables, the Cox and Snell R^2 equaled 11.00%, while the Nagelkerke R^2 equaled 17.01%. Based on this model, 79.9% of the analyst was correctly classified to be in group 2. So in the overall model, 79.9% of the sample was classified correctly.

In terms of the variables themselves, the ones in which there was significant difference between the groups were those of 'unlikely- could happen but rare (typically once a year)', 'possible - could happen occasionally (on average quarterly).' When interpreting the 'B'-values for the model, it indicate that on a scale from 1 to 5, for each unit increase in the analyst's amount of liking QRA, the probability of being in group 1 would increase by 16.03%.

However, this variable was not statistically significant for classifying the analysts correctly in the two groups. On the same scale, for each unit increase for the variable of 'likely - could happen often (on average once a month),' Almost certain- could happen frequently (once a week)' had a 39.2% decrease in their probability of being in group 1. However, for each unit increase in the analyst's agreement that QRA is easy, those analyst would increase their probabilities of being in group 1 by 30.1%. In addition, the same group 1 analyst was most likely to agree that they would like a QRA since for each unit increase of agreement that they wanted to pursue QRA, the probability of being in the group 1 would increase by 31.6%.

Risk Associated with Below Target of Allocation of Infrastructure (RIFR)

The second logistic regression that was performed included four variables that examined the risk associated with below target of allocation of infrastructure (RIFR). Overall chi-square test for the logistic model was significant ($\chi^2 = 63.010$; $p < 0.05$). In addition, the Hosmer and Lemeshow test was non-significant with a chi-square ($\chi^2 = 3.900$ p-value = 0.643) which indicated that there was a good model fit since the data did not significantly deviate from the model. From the four variables in the model, the variable of needing to 'likely - could happen often (on average once a month)' or the notes was the only significant variable. The variables of almost certain- could happen frequently (once a week), was not significant in correctly classifying the analyst into groups 1 and 2. However, based on this logistic model, 71.6% of the cases were classified correctly. More specifically, 48.3% of the group 2 was classified correctly, as well as 76.4% of the group 1. However, there was not a large proportion of the analyst's grouping variance that was explained by these variables, since the Cox and Snell R^2 equaled 4.4%, while the Nagelkerke R^2 equaled 7.3%. When interpreting the significant variable from this model, a researcher could see that for each unit increase in agreement (on a five point scale) for the variable of ''likely - could happen often (on average once a month),'' the probability of being in the group 1 decreased by 45.6%. This indicates that the group 2 tend to rely on a 'likely - could happen often (on average once a month)', in QRA. Where the average agreement for the importance of 'likely - could happen often (on average once a month)' for the group 1 was1.64, in contrast to the group 2 who had an average value of 3.02. What was also interesting was that group 1 tended to agree more strongly on the thesis that, for a good QRA, an analyst needs to understand the practices and content of risk analysis.

In order to eliminate multicolinearity issues that might exist between all the variables that were used in the two models used in the inferential analysis, one last logistic regression was performed that originally included all of the variables used in the previous models. Once the model was run, the non-significant variables were deleted from the model, which led to the final model. This last model was significant ($\chi^2 = 284.301$; $p=0.000$), while the Hosmer and Lemeshow test was non-significant with a Chi-square of 29.315 p-value > 0.05 which indicated that there was not a good model fit, since the data significantly deviate from the model. A large proportion of the variance of the dependent variable was explained by this final model, since the Cox and Snell R^2 of 29.4%, and a Nagelkerke R^2 of 31.9%. In addition, 69.4% of the cases were

classified correctly with these variables. From these cases, 64.4% were in the group 2, while 75.7% were in group 1. The distribution as well suggested that for each additional level of infrastructure the analyst had a 34.4% higher probability of being in the group 1. The variables that had the strongest effect based on this analysis were those of pass rate. On a five-point scale, for each additional increase in the amount of time reported that they (analyst) spent their probability of being in group 1 decreased by 49.4%. On the same scale, for each additional increase in the amount of time reported that they spent on human capital, their probability of being in group 1 decreased by 14.3%.

To sum up the findings of the *likelihood of occurrence of risk* in this section, an analyst needs to take cognisance of various model(s) that could be used in predicting the likelihood of occurrence of risk factors. As in this case, this was predominantly base on the likelihood of occurrence using percentage frequency as shown in the various indexes. Note that other model(s) other percentages may be suitable

The findings of the likelihood of occurrence of risk in this section suggest that the University needs to take cognisance of various model(s) that can be used in predicting the likelihood of occurrence of risk factors. In this view though, the main findings of the section included: (1) once in an academic year there is the likelihood of not meeting the target of 3rd stream income (2) with regards to the likelihood of not meeting the target in pass rates for students in the institution, a similar view was revealed (3) similarly, the notion that once a year, there was the likelihood of not meeting percentage throughput targets was a matter of concern (4) poor service culture was a major challenge that impacted on the university's sustainability which impacts on its reputation (5) it was also revealed that the institution was not likely to meet the target set in terms of teaching and academic staff qualification appropriated by the institution in an academic year.

Due to the findings of the study, it was suggested that to derive an overall likelihood rating that indicates the probability that a potential risk may be exercised within the construct of an associated threat environment, the following governing factors must be considered: (1) threat-source motivation and capability (2) nature of the vulnerability (3) existence and effectiveness of current controls. Lin (respondent) summed it all by saying that "…this information can be obtained from existing organisational documentation, such as the mission impact analysis report or asset criticality assessment report".

CONCLUSION

The findings of the *likelihood of occurrence of risk* suggest that a risk analyst needs to take cognisance of various quantitative model(s) that could be used in predicting the likelihood of occurrence of risk factors. In this regard this first of the two-phased study was predominantly base on the likelihood of occurrence using percentage frequency. In this view though, the main findings of the section included that: (1) the data (81.3%) showed that the likelihood of occurrence of risk associated with below target of 3rd stream income was likely not to be met, once in an academic year (2) with regards to the likelihood of not meeting the target in pass rates for students in the institution, a similar (70.3%) view as happening once within a year was revealed (3) similarly, the notion that once a year there is the likelihood (65.6%) of not meeting percentage throughput targets was a matter of concern (5) poor service culture was a major challenge that impacted on the university's sustainability which impacts on its reputation (6) it was revealed that that the institution was not likely (67.2%) to meet the target set in terms of teaching and academic staff qualification appropriated by the institution. Thus, in terms of academic staff, particularly academic staff qualification targets set forth by the university, the data revealed that where as there is a low (15.6%) percentage likelihood of occurrence of risk associated with not meeting a target set forth by the university in relation to qualified staff with masters and doctoral degrees, majority (73.4%) responded that the likelihood of risk of not meeting the target was serious matter of concern.

RECOMMENDATIONS

Due to the findings of the study, it is suggested that to derive an overall likelihood rating that indicates the probability that a potential risk may be exercised within the construct of an associated threat environment, the following governing factors must be considered by risk analyst: (1) threat-source motivation and capability (2) nature of the vulnerability (3) existence and effectiveness of current controls.

On the other hand though, the next major step in measuring likelihood of risk is to determine the adverse impact resulting from a successful threat exercise of risks.

REFERENCES

Cohen J, Cohen P, West SG, Aiken LS 2006. *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences*. 3rd Edition. Mahwah, NJ: Lawrence Erlbaum Associates.

Hamilton LC 2003. *Statistics with Stata.* Duxbury: Publisher Unknown.

Hedeker D 2003. *A Mixed-effects Multinomial Logistic Regression Model*. UK: John Wiley and Sons, Ltd.

King III Report 2009. King Committee on Governance: Draft Code of Governance Principles for South Africa. South Africa. Pretoria.

Markowitz HM 1957. The elimination form of the inverse and it's application to linear programming. *Management Science,* 3(3): 255–269.

McNeil AJ, Frey R, Embrechts P 2005. *Quantitative Risk Management: Concepts, Techniques, and Tools*. Princeton: Princeton University Press.

Mishra A, El-Osta H 2002. *Risk Management through Enterprise Diversification: A Farm-level Analysis.* CA: AAEA Annual Meeting, Long Beach.

Nicholas JM 2004. Project *Management for Business and Engineering: Principles and Practices*. 2nd Edition. Burlington, MA: Butterworth Heinemann.

Nicholas JM, Steyn H 2008. *Project Management for Business and Engineering: Principles and Practices*. 3rd Edition. Burlington, MA: Butterworth Heineman.

Standard and Poor 2006. *Evaluating Risk Appetite: A Fundamental Process of Enterprise Risk Management.* NY: S and P Publications.

Stoney C 2007. *Risk Management: A Guide to its Relevance and Application in Quality Management and Enhancement*. Leeds Metropolitan University: Publisher unknown.