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ASSESSMENT OF SUPPLIER RISK FOR COPPER PROCUREMENT

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Abstract. Procurement risk management (PRM) requires a good understanding and assessment of all potential risks. As the procurement industry mostly functions globally and the supply–demand chain forms a dependency structure among all interested parties, the quantification of risks related to the suppliers gain importance. This study presents a systematic PRM to evaluate and quantify the risks of a commodity associated to its suppliers. The probabilistic set up using total probability theorem on the information collected using risk management tools, such as expert opinion, charts, survey and historical realizations are imposed to quantify the risks. The resulting probabilities are utilized to construct a risk matrix which illustrates the performance of each supplier at every potential risk source. An application to a copper procurement as case study is done based on the risk management process evaluation. The quantification of the supplier's risk with respect to a risk ranking illustration in copper procurement is exposed to indicate the effectiveness of the methodology and the necessity of such evaluation in decision making.

1. Introduction

The procurement process is formed by supply management strategy and tactics which covers every stages of the production such as decision making, supplier's suitability, and satisfying customer needs. Company management information system and decision making tools should support the procurement process. Therefore, procurement process of a company should be identified carefully and be employed [15]. Procurement risk of an organization arises when the marginal external dependencies such as supply chain robustness, supplier's viability, poor supplier performance, fraud or bankruptcy threaten the performance of the company. The company may fail to fulfill its requirements due to a unexpected delay from its suppliers. Considering high demand on commodities such as oil, copper, gold which are also investment–mediums in the financial markets, insufficiency in supply endangers the

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survival of the company. The production will slow down, the commodity prices will rise leading to unpredictable financial and reputation losses. For these reasons, it gained high importance to determine the risks associated to the market suppliers.

In market conditions and behaviors' aspect, different risks could be observed. Volatility at the market, unexpected regulations or law changes, lack of early warning of price changes (hedge system), currency risk, and monopolies could be evaluated as market risk. During the procurement process, uncertainty of the raw materials procurement and supplier selection constitute major risks. Therefore, supply chain vulnerability is one of the weak links for the companies and in top ten most dangerous risks in the world [1]. Since the supply chain is a risk related procurement process, it closely relates to the procurement risk analysis and procurement risk management (PRM) [15]. The risks stress the importance of good procurement process and PRM has to be considered simultaneously [15].

There are many risks in the absence of PRM. Without PRM, company's profit, budget, and cash flow may damage. Customer and company relationship are directly related to the procurement process. Any delay at the procurement reflects to the product termini date; especially, for the companies which use "Just In Time" production technique [10]. Additionally, companies might lose their procurement negotiating average or faces internal and external fraud. On the other hand, brand reputation and company's reputation might be damaged and recovery of those takes time [15].

Earlier studies showed that when supply arrangements were altered because of the change in production system, procurement process tend to lag. Nonetheless, companies having a proper procurement process are more productive in new product planning [6]. If a company produces hi–tech components and products, company's procurement process has more volatile behavior. In such companies, uncertainty in product demand and volatility in prices is important for company's revenues. Long–term binding contracts and future contracts might be useful at its position [13]. [5] explained three types of risks which are named as supply risk, demand risk and process risk. Those kind of risks are in relation to three types of collaboration, namely supplier collaboration, customer collaboration and internal collaboration, as a mechanism to mitigate those risks. They emphasized that the supply risk and demand risk originated from external operations, while process risks from internal operations. Furthermore, process risk is raised from the unforeseen in the supply or customer demands. The results also showed that by collaboration each supply chain risk type can be mitigated.

The studies in the literature in quantifying the supplier's risk in the frame of PRM are limited. [16] reviewed different quantitative methods for supply chain management risks and numerous related supply chain risk management strategies were examined in the research literature with actual practices. [17] identified the recent development in supply chain risk management. [8] described major threats to the supply chains and focuses on the inbound/supplier side part of the supply

chain. They explained the way Supply Chain Risk Management was used to identify threats, assessed the risks, and determined what actions should be taken to manage them. They also emphasized the outcome of the risk assessments which can guide firms to handle risks, through forecasting, appropriate use of single or multiple suppliers, risk sharing, information sharing and collaboration with suppliers, flexible supplier relationships, and security prevention measures. [11] explained one group of supply chain risks which were named as current risks generated by the suppliers and their relations to the position of companies in the chain and the current economic fluctuations. Moreover, they included how to mitigate these risks. Different factors were related to supplier's side like the ability of supplier, his responsibility, economic status and location. They completed the study in two stages by means of a questionnaire analysis and follow–up of multiple case studies. The survey results showed certain signals of increasing dependence on the suppliers, deepening imbalances in the supply chains and decreasing opportunities of reducing the presence of risks.

In addition, there are similar studies like [18] which is analyzed supply chain risk management perspective by conducting a survey with 67 manufacturing companies in German automotive industry. After the identification of key drivers, the study explains risks in supply chain by analyzing the likelihood of occurrence and their possible effect upon the supply chain; moreover, the authors showed their results on the probability–impact matrix. [2] conducted a study with 3 stages: survey,Bow–Tie analysis, and fuzzy inference system (FIS). Questionnaires are used to determine risk factors and their likelihoods. The expert knowledge, historical data, snd supply chain structure are used for potential risk identification. [12] investigated risks of the effective implementation and adoption green supplier chain (GSC). They proposed a two–phased reserved approach. In first phase, 6 main risk categories and 25 sub–risk categories for GSC. Inputs of the approach are taken by expert opinions from industry. The second phase shows the usage of the fuzzy analytic hierarchy process (fuzzy AHP). [14] proposed a survey based study for risk management in supply chains. Their aim is to provide a powerful and user friendly tool for risk management. In first step, they collected expert opinions from mostly German and Belgium industry by 70 companies. They found the current situation of risk management tools usage in industry and new requirements.

However, there are no studies in the literature addressing to the quantification of the supplier's risk, especially for copper commodity. For achieving this, we aim to present a straightforward approach to assess the supplier–risk in a procurement management of a commodity. A risk assessment scheme in the frame of copper procurement and its dependency on supplier's risk are taken into account. The information collected with respect to the risk prioritize methods and the composition of this methods are utilized to assess the risks associated to supplier's performance in historical encounters with the company and its position with respect to those risks. A survey based data and methodology obtanied from [4] is used to

quantify the likelihood of failure, due to the components of each risk arising from each supplier to draw a risk–picture of the procurement process via a risk matrix.

The paper is organized as follows: Section 2 presents the methodology to quantify the risk associated with each potential risks and to determine the risk matrix. The application of the methodology is applied to copper procurement in Section 3. Using the approach proposed, the likelihood of failure for each risk level and its sub–risks are quantified to set up a risk matrix. This case study is used to illustrate the importance and necessity of the assessment of the supplier's risk. The last section finalizes the paper.

2. Determination of Supplier–Risk

Risk identification with respect to suppliers requires the collection of information which allows risk manager to distinguish the similarities and differences among the suppliers. This can be achieved by many methods such as brainstorming sessions, fish–bone analyses, cause–effect diagrams and surveys. More precise information can be achieved by a questionnaire or checklists performed regularly over time to achieve the aggregation of the information. An internal survey system can be implemented to collect the required information to monitor suppliers performance and the risks associated to it. During the risk analysis of procurement activities, different risk identification techniques can be conducted.

As the first step of risk identification, procurement managers determine the possible risk areas that cause failure in procurement activities. As a result of expert opinions, main and sub–risk categories are distinguished. This stage also gives a relative distribution of risk sources in the order of their relevances. Based on the expert judgment, and/or historical realizations the weights of each main risk levels can be determined. The weights also serve as *a priori* information on the major risk sources. A questionnaire on checklists can be employed to collect additional information for understanding and quantifying each sub–risk. Therefore, overall risk for each supplier can be evaluated in terms of its sub–risks. A detailed exhibition of likelihood on the appearance of each main–risk and its sub–risks will enable us to detect the weakest chain in PM process.

A simple, but novel probabilistic approach is proposed to quantify the risk associated to each sub–risks incorporated into the total risk. We refer each response as a random outcome whose value is utilized to determine a relative (probabilistic) quantity which converts the weighted information into likelihoods.

Assuming the main sources of risk is categorized in c groups, the number of sub–risks (n_k) for each main risk may vary. To collect a profound information on sub–risks, each question in checklists is transformed into a quantitative amount (x) by assigning certain values to the responses according to their importance.

Let x_{ij} denote the nominal response to the checklist question for i^{th} year, for supplier j which is collected using either or several of the techniques mentioned

above. The likelihood of facing with each sub–risk, k, within the whole risk family is calculated as follows:

$$P_k = \frac{\sum_{j=1}^{s}\sum_{i=1}^{t} x_{ij}}{st}, \tag{2.1}$$

where $k = 1, 2, ..., n_c$, $i = 1, 2, ..., t$, $j = 1, 2, ..., s$ and $x_{ij} = 0, 0.5, 1$. P_k determines the average value of the responses for a specific checklist question over years collected from all suppliers. Therefore, the proportion of the specific sub–risk whose value is determined over the responses is calculated as

$$p_k = \frac{P_k}{\sum_k P_k} \qquad \text{for } \forall k, \tag{2.2}$$

where P_k is used for the value of facing risk k and p_k is the average value for facing risk k, n_c is number of sub–risk of c^{th} main risk level, s denotes the supplier. We assume that the risk categories are independent of each other.

To determine the likelihood of each risk category, R_c, with respect to its n_c sub–risks, the aggregate of the expected value of the responses, x_k, $k = 1, .., n_c$; $c = 1, 2, ...$, is multiplied by the respective likelihoods obtained for each of sub–risks as follows:

$$R_c = \sum_{k=1}^{n_c} p_k \times x_k \qquad c = 1, 2, .., \tag{2.3}$$

where $k = 1, 2, ..., n_c$. Therefore, for each supplier, s, the aggregate risk, $R_{s_{TOT}}$ is calculated by using the *Total Probability Theorem*

$$R_{s_{TOT}} = \sum_{j=1}^{c} w_j \times R_j. \tag{2.4}$$

Here, w_j $(j = 1, .., c)$ stands for the weights associated to each main risk category j.

Based on the risk quantification risk ranking for each supplier can be constructed using a certain deviation around its mean value.

Let μ_k be the mean and σ_k denote the standard deviation of the sub–risk. The risk levels are nominally categorized into four groups; No Risk (N), Low Risk (L), Medium Risk (M) and High Risk (H). According to the intervals defined with respect to the mean, μ_k and the standard deviation σ_k of each sub–risk the nominal categorization is applied. The risk classes are determined according to the intervals presented in Table 1. Standard deviation which determines the impact of the risk dispersed around the mean is assumed to be maximum with one standard deviation. The reason for this is, as each risk query in the questionnaire yields a nominal value which is converted to a scale between 0 and 1, the risk for each sub–classes does not exceed one standard deviation over the mean value.

TABLE 1. Risk level categorization.

$R_k = 0$	No–risk Level (N)
$0 < R_k \leq \mu_k$	Low–Risk Level (L)
$\mu_k < R_k \leq (\mu_k + \sigma_k)$	Medium–Risk Level (M)
$(\mu_k + \sigma_k) < R_k$	High–Risk Level (H)

3. Risk Assessment for Copper Procurement

The choice of the commodity as a case study is targeted on copper, since copper is one of the widely used metallic element in industry, especially manufacturing sector all over the world. Additionally, its prices have correlation with world trade level, which makes it important commodity for market analyzes. The four main reasons for selecting copper commodities are the following: (i) Copper commodities have a highly variable market structure, (ii) Problems related to the functions of copper suppliers are unpredictable, (iii) Economic crisis on copper suppliers results in failure in procurement activities, (iv) Increasing demand on copper in global markets creates a highly competitive market.

The price volatility and financial market behavior of copper market is taken out of scope of this study. The impact of hedging strategies controlling the market risk can be found in [4]. However, the financial and market risk in the frame of procurement analyses are included as risk factors. The risk analysis of procurement activities in terms of its suppliers is performed on the data collected based on the questionnaires presented in [4]. Possible risks threatening the procurement activities, their likelihoods and impacts are calculated to find out the risk level of each supplier. Current and historical data for a time span of years (between 2006-2009) relating to the procurement activities with copper suppliers is collected by using prepared checklists and risk management evaluation forms. The confidentiality policy of the company at which the questionnaires are performed requires the source of the data to be protected and the extension of the risk assessment strategy for an update is not available. The checklists are based on the analysis of questionnaire and cause–effect diagrams are constructed according to the expert opinions in the company. The checklists are used to gather inputs to evaluate the likelihood of sub–risks. Risk management evaluation forms are completed by procurement employees at the end of each business year in order to analyze different aspects of the ongoing processes. To execute the codes MS Excel, Visual Basic, MINITAB are employed for the analyses.

3.1. **Risk-level Identification.** As a result of this brainstorming sessions, hundred sub–risk categories are determined at five main risk levels. General, Strategic, Operational, Compliance and Financial are found to be the main risk levels and risk prioritization of these sources are examined thoroughly by the experts. In regard to the expert valuation, each risk source is attributed to a priori weight. Based on

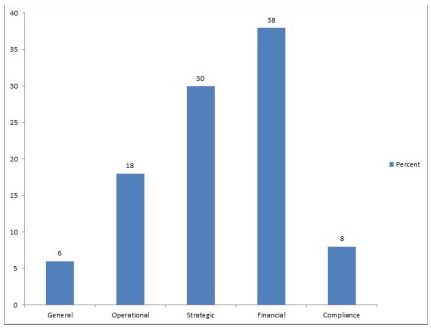

FIGURE 1. The weights for each risk level based on expert judgment.

the expert judgment, the weights of the each levels are determined as 6% for General, 30% for Strategic, 18% for Operational, 8% for Compliance, and the financial with 38% yielding the highest one as illustrated in Figure 1 [4]. The brainstorming session outcomes are used to examine all potential and real causes which produce to resolute all sub–risks for each category. As financial stability of the supplier take the first place, strategic and operational risks are found to be the risk levels having higher impact on procurement process. To give a better understanding, each risk level is explained in detail below.

Strategic risks (STR) are defined as risks that need to be considered in the evaluation of medium to long term objectives of the company. The causes which result in strategic failures in procurement are country, capacity planning and resource allocation, macroeconomics, market, price structure, production and supplier structure. Moreover, there are sub–causes referring to each problem area. For instance, the risks related to "supplier structure" are mainly covering the risks resulting from dependency to supplier, supplier's alliance/partnership agreements and supplier's vision/mission. In other words, those three sub–risk areas caused risks related to supplier structure and they affect the strategic risks of procurement activities. For this category 15 sub–risks are determined. These are Political and Country risk, Target price, Price transparency, Capacity/Planning, Production techniques, Research and Development (R&D), Technology, Economic Fluctuations, Raw material, Dependence, Alliance Partnership, Suppliers vision/mission, Supplier and Price structure.

Operational risk (OP) involves the risks linked to ongoing operations and the failure of an activity during operations [9]. By concentrating on the main causes that are classified as quality, logistics, communication, capacity and IT, eleven sub–causes are defined. While identifying those sub-causes, to achieve more specified results only the problematic areas relating to copper suppliers are considered. For instance, problems on information security, data management system and exchange

of information are the main sub–risks that result in failures in IT operations. Operational risk for the case study yields sub–risks which are Crisis communication, Exchange of information, Information security, Data management system, Logistic system, Long term, Additional capacity, Short term, Factory visits, Warranties, Quality.

On the other hand, Compliance risks (COMP) mainly arise from violations of, or the incompatibility with, the regulatory environment and the ethical standards. In addition to that, those risks cover situations related to the organizations' ability to create, capture and protect collective knowledge or ideas of employees, which are valued as non–physical assets. Four main causes affecting procurement activities are: Reputation, intellectual property, code of conduct and contracts. Nine sub–risks are listed for the Compliance risk which are Code of Conduct, Patent agreements, Intellectual Property Rights, Collective knowledge, Sub–contract risks, Special contracts, Regulatory environment risks, Unreliable supplier and Bad reputation.

Within the procurement activities, financial instability are the most crucial risk yielding many sub–risks. Supplier's liquidity and capital structure, exchange rate fluctuations on the capital market, variations in the commodity prices and risks relating to the financial health of the supplier are covered in this category. These risks affect the supplier's financial stability and the potential results of the company's operations which will eventually lead to significant supply problems for the company. Additionally, risks covering the supplier's management structure are also assumed to have financial effects on procurement activities, as those risks are directly effecting the economic situation and financial values of the supplier. The highest risk category Financial (FIN) yields 10 sub–risk categories. These are: Financial condition, Change in management, Retirement management risk, Founder-business relationship, Managerial skills, Capital structure, Monitoring, Financial obligations, Cash flow and Exchange rate. Quantitative modeling and analysis of market risk due to price changes ae not taken into account.

Additional to these categories, 7 significant sub–risks are listed under General (GEN) category which are Production Techniques/Plans, Local/Global Supplier, Registration to the internal survey system, Communication, Previous problems, Information. For each risk category, sub–risks and the probabilities associated to each sub–risk are determined according to the methodology presented in Section 2.

3.2. **Risk Level Quantification.** To the failure due to the risks listed systematically and identify the present state of procurement activities, a survey is performed through checklists having multiple choice structure. Each question yield three possible answers: "Yes", "No" and "Do not know". These possible answers for each question designed to measure the impact of sub–risks are weighted as 0, 1 and 0.5 proportional to the impact of the question. "Yes" refers to the supplier having an appropriate total quality management system and the likelihood of facing quality issues with the supplier is low. In case, "Do not know", concludes that the quality

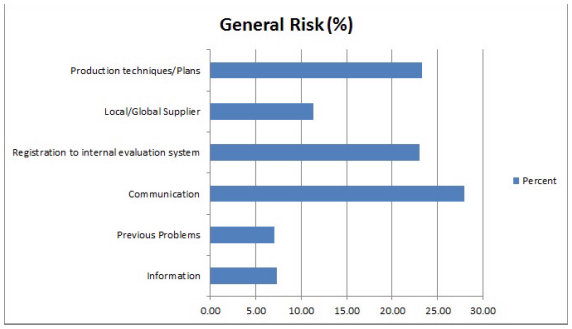

FIGURE 2. Sub–risk likelihoods for General Risk.

processes of the supplier are totally unknown, which indicates a medium level risk. Lastly, "No", informs a high possibility of having quality problems with a high risk. The checklists are completed by local buyers from different locations over the world demanding copper products from selected seven suppliers, coded as A to G. The suppliers are globally active companies that the firm trades with over the years.

The probabilities for each risk category and its sub–risk categories are evaluated with respect to Equations 2.1– 2.3. Figures 2- 6 expose the failure probabilities due to the sub–risks for each risk levels. Table 2 indicates the failure probabilities, the mean and standard deviations of each sub–risks. It is noticed that, the maximum deviation from the mean response ranges between 0.11 and 0.44 and the average value of the weighted responses rage between 0.051 and 0.921. General risk (GEN) is influenced mostly by communication, because of language differences between the company and the suppliers; the inefficient/inappropriate production techniques/plans of the supplier, and unregistered suppliers to the supplier information system which may cause a lack of evaluations concerning the supplier (Figure 2). As the production of the company is highly dependent on the supplier, dependency, fluctuations in raw material market, inappropriate use of technology list on the most significant sub–risk items in Strategic risks. Additionally, the risks relating to the supplier's alliance/partnership agreements, which affect relations and the supplier's ineffective capacity planning have medium likelihood. Moreover, not having a transparent price, in other words, not being able to see all the costs of the order clearly, is another medium level strategic risk as presented in Figure 3.

In Operational risks the most likely sub–risk is the uncertainty of supplier's long–term capacity, which is followed by short–term and additional capacity (Figure 4). Also, lack of visits to the supplier's factory is a risk as regular visits would capture the operational and capacity related chances quickly. Crisis communication, which is the process of having a continuous information flow between the cross–sectional departments of the company and the supplier, has to be developed to increase the speed and efficiency of risk management, by means of risk response/mitigation

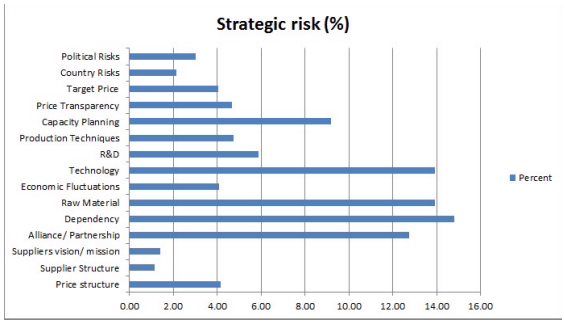

FIGURE 3. Sub–risk likelihoods for Strategic Risk.

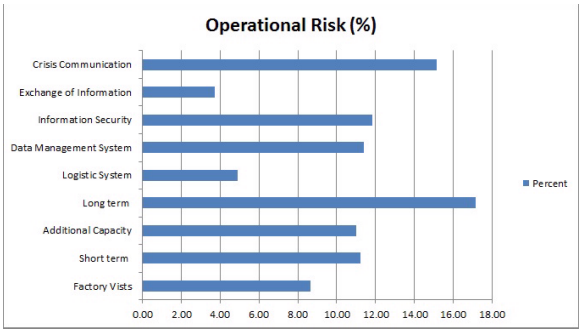

FIGURE 4. Sub–risk likelihoods for Operational Risk.

plans. Besides, although most of the suppliers do not have clearly defined warranties, the likelihood of having quality related risks is very unlikely, such as 0.01, because all the suppliers have appropriate quality management systems. As compliance risk, the highest sub–risk is found to be the patent issues, as the copper suppliers generally do not have patent agreements. The second highly probable risk area is the threats relating to the suppliers sub–contracts, which may cause some limitations regarding production/capacity or information flow problems. The reputation and reliability of the supplier are seen as the less risky areas with lower probabilities (Figure 5). The final risk category, Financial is lead by capital structure and managerial risks followed by the founder-business relation. Family businesses having no structured management system is regarded as a likely threat to the on-going procurement (Figure 6). Even though exchange rate is regarded as one of the main market risks, the survey is not significant in this sub–risk as, all suppliers, except one, trade with the same currency.

TABLE 2. Failure likelihood of each category.

Risk	Sub-Risk	Failure Like.	Mean	St. Dev
Strategic	Price structure	0.042	0.185	0.310
	Supplier Structure	0.012	0.106	0.218
	Suppliers vision–mission	0.014	0.147	0.220
	Alliance–Partnership	0.128	0.471	0.375
	Dependency	0.148	0.353	0.276
	Raw Material	0.139	0.921	0.150
	Economic Fluctuations	0.041	0.282	0.390
	Technology	0,139	0,576	0,208
	R and D	0.059	0.406	0.316
	Production Techniques	0.048	0.305	0.303
	Capacity Planning	0.092	0.324	0.309
	Price Transparency	0.047	0.332	0.381
	Target Price	0.041	0.271	0.279
	Country Risks	0.021	0.120	0.328
	Political Risks	0.030	0.193	0.343
General	Information	0.073	0.206	0.309
	Previous Problems	0.071	0.265	0.400
	Communication	0.279	0.678	0.439
	Registration–Internat System	0.230	0.221	0.243
	Local/Global Supplier	0.114	0.133	0.281
	Production techniques–Plans	0.233	0.559	0.348
Operational	Quality	0.010	0.040	0.140
	Warranties	0.040	0.200	0.350
	Factory Visits	0.087	0.571	0.440
	Short term	0.112	0.367	0.426
	Additional Capacity	0.110	0.429	0.440
	Long term	0.171	0.171	0.297
	Logistic System	0.049	0.275	0.275
	Data Management System	0.114	0.419	0.270
	Information Security	0.118	0.375	0.240
	Exchange of Information	0.037	0.200	0.296
	Crisis Communication	0.152	0.224	0.275
Financial	Exchange Rate	0.056	0.147	0.294
	Cash Flow	0.093	0.294	0.254
	Financial Obligations	0.020	0.118	0.219
	Monitoring Financial Situation	0.059	0.294	0.356
	Capital Structure	0.169	0.441	0.166
	Managerial Risks	0.161	0.500	0.306
	Founder-Businessman relationship	0.133	0.533	0.352
	Retirement Management risk	0.085	0.294	0.254
	Change in management	0.119	0.412	0.196
	Financial Condition	0.105	0.206	0.254
Compliance	Bad Reputation	0.021	0.078	0.122
	Unreliable Supplier	0.017	0.052	0.117
	Regulatory Environment Risk	0.101	0.206	0.309
	Special Contracts	0.055	0.324	0.309
	Sub-Contract Risk	0.206	0.500	0.395
	Collective Knowledge	0.084	0.235	0.257
	Intellectual Property Rights	0.092	0.235	0.257
	Patent Agreements	0.370	0.824	0.246
	Company's Code of conduct	0.055	0.324	0.219

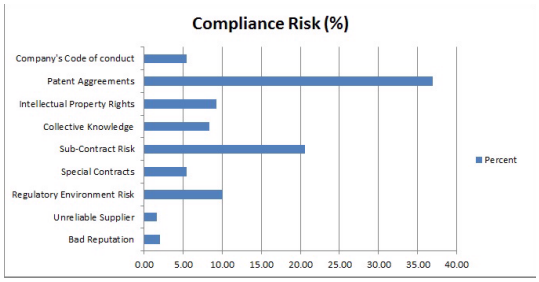

FIGURE 5. Sub–risk likelihood for Compliance Risk.

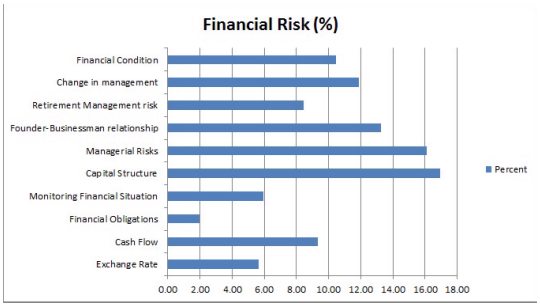

FIGURE 6. Sub–risk likelihoods for Financial Risk.

To determine the likelihood of each risk category, R_c, with respect to its n_c sub–risks, for each risk levels c=GEN, STR, OP, FIN, COMP, the aggregate of the expected value of the responses, x_k, $k = 1, .., n_c$; is multiplied by the associated likelihoods. Having calculated these probabilities, the aggregate risk $R_{s_{TOT}}$ is calculated for each supplier, s = A, B, C, D, E, F, G, by using the Total Probability Theorem as defined in Section 2. Table 3 illustrates that supplier F has the significant values in GEN, STR and COMP risk areas compared to the other suppliers. Nevertheless, Supplier A comes up with the highest risk value a total, 0.451. This indicates that the procurement activities with Supplier A have the highest level of risk compared to other suppliers. Moreover, the supplier G is seen as the less risky of them all with a total risk value of 0.262.

3.3. **Supplier's Risk Ranking.** Risk ranking based on main risk levels and subcategories is rephrased in four categories as N, L, M, H referring none to the highest degree of risk gradually as mentioned earlier. The risk levels for the risk categories and suppliers are illustrated as a risk matrix in Table 4 which depicts a comparative and illustrative picture on the highest and lowest risk levels for each supplier. According to the results of this risk categorization table, the suppliers A and B have the highest risk levels by having mostly medium and high risk in most of the risk

TABLE 3. Risk valuation for each category and supplier.

		Supplier						
Risk	**Weight (%)**	**A**	**B**	**C**	**D**	**E**	**F**	**G**
General	6	0.578	0.333	0.392	0.461	0.438	0.629	0.331
Strategic	30	0.478	0.472	0.428	0.397	0.485	0.503	0.283
Operational	18	0.315	0.373	0.195	0.318	0.296	0.340	0.176
Financial	38	0.467	0.474	0.258	0.395	0.326	0.290	0.253
Compliance	8	0.481	0.483	0.477	0.464	0.547	0.792	0.370
Total	100	0.451	0.448	0.323	0.391	0.392	0.423	0.262

areas. Additionally, because of being a low-cost country supplier and facing often with exchange rate fluctuations, Supplier F also shows high risk indications, especially in financial and compliance areas. On the other hand, Supplier G is observed to be the least risky supplier. This is because it is a bigger supplier compared to other ones and conducting business in global market. Due to those characteristics of Supplier G, for most of the sub–risk levels no risk values are found. The remaining risk-levels show mainly low–risk.

The Risk Matrix can be used as a guideline for managers during their decision-making process so that they can more adequately direct their attention to the activities of high risk level suppliers. In addition, the risk categorization table is analyzed according to the risk criteria and sub–risk areas. Generally, the STR and FIN risk criteria are two problematic areas in the procurement activities for copper commodities. Within the STR risk criterion, especially the supplier's alliance/partnership agreements and the company's dependence to the supplier are the two main sub–risk areas. Besides, their capital structure and financial conditions are seen as the critical financial criterion sub–risks as well as the management problems of suppliers. The kite diagram demonstrates how less likely to have procurement problems due to operational risks. In other words, excepting capacity related sub–risks, low risk levels can be predicted for the operational risks.

TABLE 4. Risk ranking matrix for each supplier.

Risk	Sub-Risk	Supplier A	B	C	D	E	F	G
Strategic	Price structure	N	M	M	L	M	H	N
	Supplier Structure	M	M	M	N	N	M	N
	Suppliers vision–mission	H	M	N	L	N	N	N
	Alliance–Partnership	M	M	M	M	M	M	N
	Dependency	M	M	L	M	M	M	N
	Raw Material	L	L	M	M	L	M	M
	Economic Fluctuations	M	L	N		L	H	N
	Technology	M	L	M	L	M	L	L
	R and D	L	L	L	L	H	M	L
	Production Techniques	M	L	M	M	L	L	L
	Capacity Planning	M	M	L	L	M	L	L
	Price Transparency	M	M	M	L	M	L	L
	Target Price	M	M	N	L	L	L	M
	Country Risks	N	N	N	N	N	H	N
	Political Risks	L	L	N	L	N	H	N
General	Information	M	M	N	L	M	N	N
	Previous Problems	H	L	N	L	N	N	N
	Communication	M	L	M	L	M	M	L
	Registration–InternaL System	H	L	N	H	N	H	H
	Local/Global Supplier	L	N	N	L	H	N	N
	Production techniques/Plans	L	L	M	M	L	H	N
Operational	Quality	L	N	N	N	N	N	N
	Warranties	L	L	N	L	N	N	H
	Factory Vists	L	M	L	M	L	M	N
	Short term	L	M	L	M	M	M	M
	Additional Capacity	L	M	H	H	N	H	N
	Long term	H	L	N	M	N	N	N
	Logistic System	H	L	L	M	M	L	M
	Data Management System	M	L	L	L	M	M	M
	Information Security	H	L	L	L	M	N	N
	Exchange of Information	H	M	M	N	M	N	N
	Crisis Communication	M	M	L	L	M	L	N
Financial	Exchange Rate	L	M	N	L	N	H	N
	Cash Flow	L	M	L	L	L	M	N
	Financial Obligations	M	M	N	M	N	N	N
	Monitoring Financial Situation	M	M	N	M	L	N	N
	Capital Structure	M	M	M	M	L	M	N
	Managerial Risks	M	M	L	M	M	N	M
	Founder-Businessman relationship	M	M	L	M	L	N	L
	Retirement Management risk	M	L	L	L	M	M	N
	Change in Management	M	M	L	L	L	M	M
	Financial Condition	M	H	M	M	M	N	N
Compliance	Bad Reputation	H	L	M	L	N	N	N
	Unreliable Supplier	M	N	M	N	N	N	N
	Regulatory Environment Risk	M	L	N	M	N	H	N
	Special Contracts	H	H	N	L	N	N	N
	Sub-Contract Risk	H	L	M	M	M	H	N
	Collective Knowledge	M	M	N	M	N	H	N
	Intellectual Property Rights	M	L	N	M	M	H	N
	Patent Agreements	L	M	M	L	M	M	M
	Company's Code of conduct	M	N	N	N	N	M	N

4. Concluding Comments

This paper aims to determine the quantification of supplier risk for a procurement company using risk management and probability under Procurement Risk Management (PRM) scheme. Different levels of risks and sub–risks of a company's procurement process in the aspects of company's suppliers are investigated for copper industry. Risk management process in the stage of risk quantification is explored using expert opinions, charts and checklists, and questionnaires on the suppliers. A weighted likelihood for each sub–categories are determined to evaluate first the failure likelihood from each risk level and then, utilizing this information to determine the risk of each supplier separately. The resultant probabilities are converted into a risk categorization matrix which enables decision makers to distinguish the weakest function/department of each supplier.

Even though the target commodity is chosen as copper, practical implementation of the proposed methodology can be applied to any other commodities yielding multi–dimensional sources of risks. Specifically the procurement analyses depending on uncontrolled outside sources can be evaluated through risk management techniques.

Since the procurement process is cross–department process, we conclude that financial and strategic decisions of the suppliers influence the procurement process mostly. Especially, capital structure of the suppliers and dependency of the company to suppliers, communication, production technology, long–term contracts, and patent agreements contribute highly to the performance and reliability of the supplier significantly. Furthermore, a company without procurement risk management system can be regarded as at the highest risk. Market conditions and external dependency, such as to its suppliers should be observed by the procurement managers before every purchasing step and keep tracking at the end of termini date. This study shows that for productive and effective process in the company, PRM is a good tool for financial achievements.

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