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Developing a Risk Assessment Model for non-Technical Risk in Energy Sector

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Abstract

Risk Management is one of the most relevant approaches and systematic applications of strategies, procedures and practices management that have been introduced in literatures for identifying and analysing risks which exist through the whole life of a product ,a process or services. Therefore, the aim of this paper is to propose a risk assessment model that will be implemented to the energy sector, particularly to power plants. This model combines the Analytic Hierarchy Process (AHP) technique with a new enhanced Balance Score Card (BSC). AHP is constructed to determine the weights and the priorities for all perspectives and risk indicators that involved in the BSC. The novelty in this paper is not only in using the BSC for risk assessment, but also, in developing a new BSC with six perspectives, which are sustainability perspective; economic; learning and growth; internal and operational business process; supply chain and customer/demand perspective. Another three contributions of this paper are firstly, including the sustainability dimension in BSC, and covering nine risk categories, which comprise 84 risk indicators that have been distributed across the six risk BSC perspectives. Secondly, assessing the non-technical risks in power plants and finally, this research will concentrate on the strategic level instead of the operational level where the majority of researches focus on latter but the former is far less researched. The created model will provide an effective measurement for the risks particularly, in the power plants sector. The results of this study demonstrate that the supply chain risks perspective is the keystone for the decision making process. Furthermore, these risk indicators with the new structure of BSC with six perspectives, help in achieving the organisation mission and vision in addition to affording a robust risk assessment model. The inputs of this model are composed from a previous stage using a modified Failure Mode and Effect Analysis (FMEA) (which has been used the Exponential Weighted Geometric Mean (EWGM)) to understand and analyse all risks, after which, the results of the developed FMEA which are the Risk Priority Numbers (RPN's), have been used to build the AHP-BSC risk model. These risks are collected with difficulty from various literatures. This study will be validated in the next stage in power plants in the Middle East.

Keywords:

Analytic Hierarchy Process (AHP), Balance Scorecard (BSC), Risk Indicators (RI), Risk Priority Number (RPN), Exponential Weighted Geometric Mean (EWGM)) and Risk Management (RM).

I. INTRODUCTION

Risk Management is one of the most relevant approaches and systematic application of strategies, procedures and practices management that have been introduced to identifying and analysing risks which exist through the whole life of a product or a process. The risk management needs in energy sector emerges from the role of power plants which is very crucial for continuous and reliable energy supply (Chan, 2009). The energy sector faces a broad groups of risks (demand, transportation and market conditions….etc.) which can interrupt the operations and cause significant adverse effects in the energy sector either short-term or long term performance of the energy organisation. Risks have presented in every stage, from the commission phase to the decommission of power plants. Thus, it is important to identify the risks in all stages: commissioning and starting; fuel supply and delivering; operating, running, maintenance and Ash disposal; and finally the decommission stage). These risks will result from a process, products, natural disasters, equipment failures, terrorist attacks, political, economic or environmental concerns (Achebe, 2011). Due to that, it is important to develop a comprehensive, coherent, methodological, structured and systematic approach to identify and assess risks. Consequently, the risk mitigation plans can be developed and implemented**.**

Accordingly, this paper aims to develop a risk assessment model that will be implemented to power plants. This model combines the AHP technique with a new enhanced BSC. AHP has been used to calculate the weights and the priorities for all risk perspectives and each risk indicators. The BSC is used as a risk assessment tool with six perspectives not four perspectives as the traditional BSC. These perspectives are sustainability; economic; learning and growth; internal and operational business process; supply chain and customer/demand perspectives. This paper covering nine risk categories, which comprise 84 risk indicators that have been, distributed across the six risk BSC perspectives. This research will concentrate on the strategic level instead of the operational level therefore, all the selected risks are non-technical risks that will help the top management in the decision making process.

II. BACKGROUND

According to (Smart and Creelman, 2013) ISO31000 standard defines risk as the effect of uncertainty on objectives. These objectives may have various aspects: financial, health and safety, and environmental goals, which can be applied at strategic, operation, process or product and project. This standard offers the principles that relates to the risk management process. Some of these principles are:

- Risk management is part of the decision-making process;
- Systematic, timely and structured approach to risk management contributes to efficiency and to consistent, comparable and reliable results;
- Is aligned with the organizations' external and internal context and risk profile;
- Is a dynamic, iterative and responsive to change and risk management facilitates continual improvement of the organisation.

Additionally, (Smart and Creelman, 2013) indicate that the importance of this standard is in integrating risk management with strategy, and they claim that the integration between the BSC and ISO31000 has become a main topic within these two areas. Moreover, (Keow Cheng and Hon Kam, 2008) clarify that a structured methodology risk management framework provides a systematic, logical, stringent and rigorous approach to assess and analyses the risks. Many strategic techniques are available to evaluate the performance of organisations, one of these techniques is BSC (Dag, 2010). Several years ago, the concept of BSC has been initiated by (Kaplan and Norton, 1991) as a performance measurement tool where group of measures (financial & operational) have been used to give top managers a quick and exhaustive view of the business, where the mission and the objectives of organisations translated to measurable metrics measures in four perspectives :financial performance (the strategy for profitability viewing from the perspective of the shareholder);customer satisfaction (the strategy for creating value and

differentiation from the customer's perspective; internal processes, and learning & growth. The strategic priorities for various business processes that creates customer and shareholder satisfaction; learning and growth ;design to enhance employee competencies and strategic awareness, support organisational change, innovation, and growth (Popa and Cosman, 2011).

Depending on aforementioned, applying the BSC and combining it with the AHP technique to assess non-technical risks, will help the companies to take a strategic long-term decisions. (Makajić Nikolić et al., 2011) claim that there is relatively little research on how the risk assessment methods can be used for non-technical area. Additionally, (Oblakovic, 2013) asserts that the majority of research focus on operational risk management but the strategic level is far less researched accordingly, there is a lack of comprehensive researches on the strategic level of risk management. This paper depends on the results of our previous work (ALMashaqbeh et al., 2018) of a modified FMEA and taking the RPN outputs as an input for this research. The FMEA has been applied previously to identifying and analysing the risks using the EWGM. This method combines the exponential method and the weighted geometric mean to overcome some drawbacks of the traditional FMEA. This method takes the weights of the three risk factors (severity, occurrence and detection) into account and reduce the duplications RPN's of the traditional FMEA which will provide more accurate and reasonable data than the traditional method. However, the traditional FMEA has been applied and focused only on the technical part, which is related to the operational level while in the previous research it has been used for non-technical risks at the strategic level. Furthermore, there are not any mechanisms to communicate the strategic level hence, covering all these various risk categories, makes the research more comprehensive and will help and support the organisations in energy sector to take strategic decisions, which will increase the benefit and the revenue additionally, will make the work environment safe and healthy. The input data for the BSC and AHP model have been taken from the FMEA in our previous paper and will be used in building the AHP model ,after which constructing the SD model to study the dynamic environment of non-technical risks in power plants.

Overall, the researches on risks using the BSC have focused mainly on the implementation and theoretical aspects of the phenomenon. Few organisation case studies focus on how risk is implemented in the BSC (Kotze et al., 2015). In the same way, (Kaplan, 2010) discusses that more focus needs to be done to improve the measurement and the risk management for the companies and how the risk can be integrated through the BSC.

Balanced Scorecard should include a mix of leading (performance driver) and lagging (outcome) indicators. Where lag indicators epitomise the consequences of actions which have been previously taken, while lead indicators are the measures that lead to—or drive—the results achieved in the lagging indicators (Niven, 2006). (Kaplan and Norton, 2001) discriminate between lagging and leading objectives which have been constructed for the strategic decision level of each perspective as well, the lagging indicators display if the strategic goals and objectives in each perspectives have been fulfilled or not. Meanwhile the leading indicators are very specific for the companies and show how the result should be achieved. However, the indicators integration in all perspectives can be achieved by determining the goals and objectives for the company and selecting a suitable lagging and leading indicators furthermore, they display that the lagging and leading indicators are linked and connected in the individual perspective and affected through all four perspectives of the BSC.

According to International Risk Management Standard AS/NZS ISO 31000:2009, the successful of risk management will depend on the effectiveness of the management framework that providing the foundations and the arrangements which will be embedded across all the organisation levels. For instance, the University of Adelaide tried to ensure if their risk management framework is effective or not. Consequently, principles of risk management as set in that international standard have been adopted where these principles are: Create and protect value; systematic structured and timely; dynamic, iterative and responsive to change; facilitates continual improvement of the organisation; integration of all organisation process and check if it is a part of decision making process (The University of Adelaide, 2009). Similarly, The United States Homeland Security attempts to ensure the principle of customisation where this assures includes ensuring that the organisation's risk management effort is systematic, timely, and structured depends on the values of the organisation where they claim that the risk management allows for a systematic and holistic approach to decision making process (Department of Homeland Security, 2011). In their white paper AMRAE point out that, the risk management framework provides a structured and formalised mean for bottom-up information on risks and their prioritisation. In addition to that this framework is concerned and organised systematically (AMRAE, 2015).

Risk management should be linked to the organisation's performance management and should not be separated where the performance management and the risk management are different sides for the same coin. The BSC is

considered as the most effective and popular way to this linkage where the Key Performance Indicators (KPI's) help in measuring and monitoring the organisation's performance ,then integrating the BSC with the related Key Risk Indicators (KRI's). In the integration of risks dimensions into the BSC; the same process that has been done for performance management can be done for the risk management (Ernst & Young, 2009). Indeed, as the BSC provides the organisations with tools to measure and monitor its performance, likewise, the new BSC, enhanced with KRI's, will allow a company to plan, measure and monitor its risk management at each level of the organisation. As a result, the BSC helps to translate vision and strategy of an organisation into a clear objectives that can be measured. These objectives are cascaded across the organisation. From a top-down perspective where the KPI's at a higher level are translated for KPI's at a lower level and at the top level where the Dashboard of BSC is set out for top management, with a limited number of main KPI's.

(Bearsly et al., 2006) claim that BSC is the most known strategic performance measurement tool and it occupies an enterprise wide approach where the organisation missions and strategy are linked to the organisation performance measures which can boost and concentrate to integrate the risk management with the performance measurement. The authors in this article assert that as the BSC helps the organisations to translate its vision and strategy into actions and measures at different levels of management and between long-term and short-term goals, similarly, the enhanced risk BSC with KRI's can capture the required information for the risk management objectives through the risk measures where the risk management can be monitored for all organisation levels.

(Calandro and Lane, 2006) demonstrate that the prime strength of the BSC is the level of transparency it brings to key cause and effect business linkages. The cascading effect of scorecard from various levels of an organisation can offer a common and a robust framework to investigate and manage the risks at these different levels. Conversely, one of the difficulties in BSC that don't allocate the important , priorities of perspectives and the performance indicators within each perspective (Veronese et al., 2012). (Kaplan, 2010) claims that all the objectives are linked in cause-and-effect relationships through all the perspectives (starting with employees, continuing through processes and customers finally, reach to financial performance). Furthermore, this casual linkage through the BSC guides to strategy map formulation.

Each BSC perspective influences other perspectives; the order of development is dominated by cause and effect relationships. At the top level, strategy is dictated by financial measures. An organisation's customers (the source of revenue) are the key to achieving these financial goals. The internal business process perspective is the actual work that has to be done and measured, this enables organisations to increase its scores on the customer and financial perspectives. While the measures in the learning and growth perspective would be applied to see how the organisation would manage its human capital. Additionally, this perspective is related to the internal business process, notably through the relationship formed when new processes and process improvements are set as goals (Kotze et al., 2015).

(Ittner and Larcker, 2008) display the results of a global survey that has included the risk in the BSC which are: 20% of these companies added risk measures to their BSC, and the survey also found that more than 50% expected to implement risks in their BSC in the future. Along with, (Kotze et al., 2015) in their study have found that 7.7% have used the BSC and this percent doesn't represent a large rate of adoption but, shows sample of organisations which meet the objective of the study. Relating to the total population; only 2.25% organisations have applied and added the risks with the BSC.

(Calandro and Lane, 2006) have suggested the first paper that has been used the risk scorecard framework, and they claim that this scorecard framework could be an effective tool for risk measurement and management and they clarify that the risk scorecards should be separated from performance measurement scorecard. This scorecard includes the same four perspectives of the performance BSC (financial, Customer, Internal, and Learning and Growth). In contrast, (MOELLER, 2007) describes the cubic COSO ERM framework with the three dimensions cube which includes of eight horizontal rows or risk components, four vertical columns denote to the strategic objectives and slice for various organisation levels. COSO divides their risks categories for process risks, environmental risks, and Information for decision making risks,

Integration the BSC with one of the Multi Criteria Decision Making process (MCDM) which is the AHP; has been developed in this study to overcome this difficulty thus, the related weights can be calculated. In this paper, AHP is adopted for allocating the weights for the identified risk indicators in each of the six hierarchical perspectives of the new enhanced BSC.

A. AHP

The AHP has been adopted first time for environmental assessment by Saaty (1977) after which, has been used broadly (Yang et al., 2014). AHP is a theory of measurement through pairwise comparisons derived the priority scales depends on the judgments of experts (Saaty, 2008). Furthermore, AHP has become one of the most widely used MCDM methods, and has been applied to solve different problems in various areas such as political, economic, social and management sciences (Wang and Xia, 2009). Problem breakdown is required according to the following steps (Saaty, 2008) to produce priorities and make suitable decisions:

1. Define the problem;
2. Structure the decision hierarchy from the top level with the goal of the decision, then the objectives, through the intermediate levels (criteria) to the lowest level (alternatives);
3. Construct a set of pairwise comparison matrices;
4. Use the priorities obtained from the comparisons to weigh the priorities in the below level;
5. Repeat this for every element. Then for each element in the level below add its weighed values and obtain its overall or global priority.
6. Continue this process of weighing and adding until the final priorities of the alternatives in the bottom most level are obtained.

Table 1 exhibits the scale that will be used to build the comparison matrix.

Table 1: The fundamental Scale of absolute numbers (Saaty, 2008)

Intensity of Importance	*Definition*	*Explanation*
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	A reasonable assumption
1.1–1.9	If the activities are very close	May be difficult to assign the best value but when compared with other contrasting activities the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities.

AHP will be applied to prioritise the risk indicators in power plants through assessing the weight for each risk indicators depending on relative importance of these indicators. According to (Ishizaka and Labib, 2011) , one of AHP strengths is the possibility to evaluate quantitative and qualitative criteria and alternatives on the same scale, either numerical ,verbal or graphical. Moreover, this article has represented one of the main advantages of AHP which is the absence of rank reversals due to the inconsistence. In the same way, (Hartwich, 1999) illustrates another advantage, where the qualitative information is converted into quantitative data which has been used for management decisions in addition to that, participants of the evaluation process obtaining an understanding of the decision process.

B. BSC and Sustainability

BSC can assess if the organisation is moving across the defined strategy and going correctly to satisfy its objectives and strategies. Subsequently to be effective; descriptions of financial aspect, markets served, processes to be executed, and the most important factor, the employees who will instruct the company to success must be included. Hence, when the organisations measure their progression, should take in consideration all aspects together

.Along with, the organisation can build their BSC and include five perspectives or only three (Niven, 2006), for example (Peter, 2000) in his article evaluates the performance of the process for five perspectives: financial view, employee view, customer view, societal view, and innovation view.

(Niven, 2006) represents the benefits of BSC for organisations. Such benefits include, increased financial returns, alignment the employee with the organisation goals and objectives, enhance collaboration.

BSC is a suitable tool for sustainability management hence, linking the social and environmental sustainability part give the chance to companies to follow up strategies execution process and performance (León-soriano et al., 2010).

The definition of sustainability includes three pillars: economic, environmental/ ecological, and social systems. The economic pillar assesses the economic sustainability of system to manufacturing goods or provides services continuously while the ecological pillar refers to the environmental sustainable system that preserve a stable system. In contrast, the social dimension is associated with providing social services comprises health and education, gender equity, and political accountability and participation (Assefa and Frostell, 2007). In the literature, there are various options for developing the scorecard for integrating the environmental and the social aspects with the BSC, these options are; combine them into the four existing perspectives; add new one or more perspectives regarding environmental and social pillars. Thirdly, a special sustainability BSC can be derived (Wittstruck and Teuteberg, 2011).

In this research, the new developed BSC includes six perspectives while the sustainability part combines four categories. From an extensive review of literature in the area of risk management and risk analysis in energy sector ((Regős, 2013); (Zegordi, Rezaee Nik and Nazari, 2012); (Lidong et al., 2009) ;(Makajić Nikolić et al., 2011)); (Dae-Woong, Yoonseok and Kim, 2016); (El Mokrini et al., 2016); (Dae-Woong, Yoonseok and Kim, 2016); (Radivojević and Gajović, 2014); (Samvedi, Jain and Chan, 2013); (Zegordi, Rezaee Nik and Nazari, 2012)), **84** risk indicators that can have an impact on power plants have been identified, understood, reviewed and evaluated to determine the ranks of those factors. In this study, a new comprehensive ,conceptualised risk classification framework for risk decomposition is adapted and developed using the proposed FMEA, the developed methodology would be a generic one and can be modified in some categories as per the organisation objectives, where this framework will help companies at the strategic and tactical levels decision process. The risk categories embrace **nine** categories, sustainability dimension includes **four** pillars (economic, environmental, social, and technological) and the other **five** categories are: management risks, internal business process and operational risk, supply risks, customer/demand risks and human resources risks. The contributions in this part of research are located by the number of risks that have been covered all risk types, secondly, added a fourth pillar to the sustainability dimension.

III. Methodology

In this study, the six perspectives of the new enhanced BSC have been taken as the framework for establishing the risk management model. Firstly, the RPN's of the proposed FMEA methodology have been used as the input data of AHP. Next, the BSC framework is used to study the different 84 risk indicators across six perspectives. Finally, AHP has been applied to obtain the weights of the selected risk indicators which deployed in the new BSC. Generally, the aim of this paper can be achieved by the following steps:

1. Used the results of the proposed FMEA methodology as the inputs for the AHP;
2. Constructed the new BSC framework with the six perspectives to study the selected risk indicators.
3. Calculated the weights of each risk indicators in the hierarchy.
4. Determined the key risk indicators from the AHP model.
5. Displayed the results.

IV. The BSC Framework

Several studies in the management sector have confirmed that the BSC is an appropriate and effective tool helped organisation to evaluate the performance (Zare Zardeini et al., 2014). However, as the BSC doesn't determine

the weights of indicators and perspectives, many scholars attempt to overcome this drawback by integrating the BSC with MCDM (Noori, 2015). (Yaghoobi and Haddadi, 2016) develop an integrated model of BSC and AHP to explore the performance of a telecommunications company. In their study, the authors emphasis that the BSC is an important tool of measuring business performance from the strategic implementation perspective rather than relying only on financial results where that means the BSC offers a comprehensive view of how and where the organisation is going. In contrast, the AHP is applied to calculate the weights of perspectives and indicators, which are crucial from the managerial view. Although the application of the BSC in the business and management area is well used, very little research has been applied for the risk management. There are only a few studies have shown how risk management and BSC can be integrated (Chabchoub, 2014). (Calandro and Lane, 2006) claim that they have developed the first framework integrates the risk in a scorecard, they design a risk scorecard depends on Kaplan and Norton's BSC. They show that the risk scorecard framework could be an effective tool for risk management however, the risk scorecard and the performance scorecard should be separated because this merged will reduce the usefulness as a management technique. Additionally, risk measurement and performance measurement have various activities that are executed by different employees in different departments within the organisation.

V. The New BSC Framework and Improved FMEA Results

The contribution of this paper rests on the attempt to propose a new enhanced model for risk assessment with a performance measurement tool using a BSC framework with a new six perspectives, one of them is the sustainability. Next, develops an AHP risk model. The proposed model is carried out in two phases. Firstly, after the risk indicators have been identified by a proposed FMEA methodology, the result of the methodology will use to support the AHP inputs where the Risk Indicators (RI's) can be determined and reflected on BSC. This risk model covers non-technical risks where is very limited research in this area. This research will accent on the strategic level instead of operational level where that the majority of research focus on latter but the formal is far less researched.

Figure 1, illustrates the new BSC enhanced with six perspectives with one referring to the sustainability. This BSC has been established as a control and management tool for the top management of the organisation, according to the strategic objectives, Mission and Vision. The KRI's have been defined from literature review, and will be validated in the next stage in power plants in the Middle East. Some of the KRI's are simple to found, but others are hard to obtain because the study attempts to cover different risk categories, particularly in the energy sector. Table 2 shows a part of the final summarised results of the improved FMEA, which have been extensively explained in our prior conference paper (ALMashaqbeh et al., 2018).

Fig.1: New Risk BSC with Six Perspectives

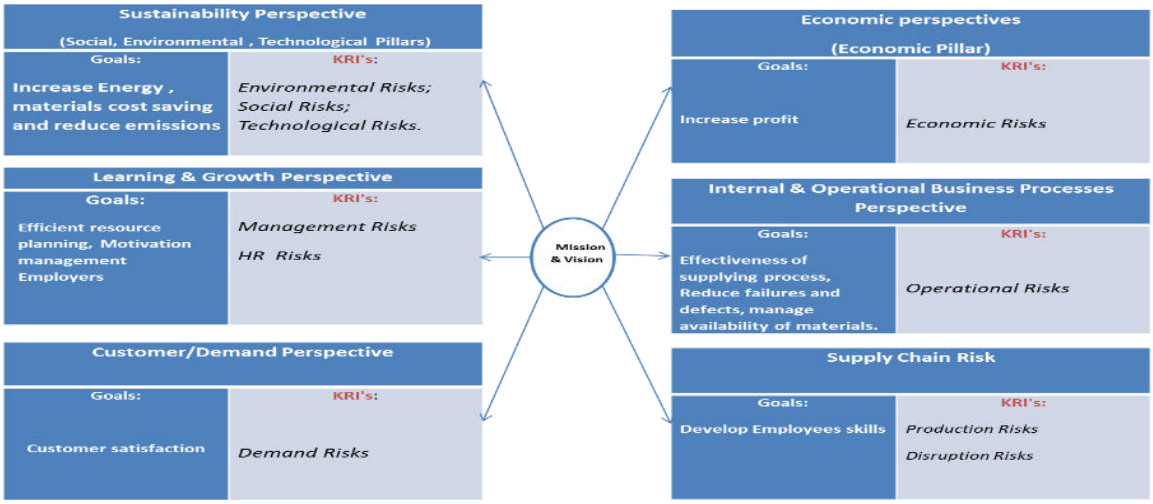


Table 2: Part of FMEA Results for some Risk Indicators of Power Plants

RI	O W_O=0.333	D W_D=0.097	S W_S=0.57	Traditional RPN	EWGM RPN	Traditional Rank	EWGM Rank
Waste handling Risk	5	4	5	100	359.190	1	1
Supplier Price Risk	5	4	5	100	359.190	1	1
Price of electricity Risk	5	3	5	75	346.980	3	2
Technical Risk	5	3	5	75	346.980	3	2
GHG emissions Risk	5	3	5	75	346.980	3	2
Lost time Injuries Risk	5	3	5	75	346.980	3	2
Noise Impact Caused by Energy System	5	3	5	75	346.980	3	2
Bad Odors Risk	5	3	5	75	346.980	3	2
Load forecasting Risk	4	4	5	80	314.000	2	3
Disruption Risks/ customer side	4	4	5	80	314.000	2	3
Solid waste Risk in thermal power plants	4	4	5	80	314.000	2	3
Soil Pollution Risk	4	4	5	80	314.000	2	3
Production risk	4	4	5	64	314.000	4	3
Disruption Risks/ supply side	4	4	5	64	314.000	4	3
Asset Depreciation Risk	4	3	5	60	303.326	5	4
Operating cost Risk	4	3	5	60	303.326	5	4
Raw material and product quality standards (fuel) Risk	4	3	5	60	303.326	5	4
Delay in schedule Risk	4	3	5	60	303.326	5	4
Employee safety Risk	4	3	5	60	303.326	5	4
Human Toxicity Risk	4	3	5	60	303.326	5	4
Labour strikes Risk	4	3	5	60	303.326	5	4

Table 2, exhibits the results of applying the traditional FMEA and the developed FMEA using the EWGM. These risks indicators have been derived from various risks categories and have been ranked as shown in Table 2 depending on their priorities from the FMEA outputs either (traditional FMEA or the developed FMEA). Some of these risks are environmental risks, economic risks, internal and business process risks and human resources risks. As Table 2 displays, the waste handling and the supplier price risks are top ranked risks which mean that these risks are the most important risks. But, in other risks there are differences in the ranking, these differences show that the results of the improved methodology are given more accurate, practical and reasonable results (ex. In practical, the price of electricity (which has been ranked as the second risk in the EWGM) is more important than the load forecasting risk (which has been ranked as the third risk in the traditional FMEA).

VI. Results & Analysis:

Depending on literature review and some real examples for unavailable indicators. The new enhanced BSC has been developed as a hierarchical structure of the BSC risk management with six perspectives and 84 risk indicators. These indicators have been classified for nine categories through the six perspectives, which help in achieving the organisation mission and vision in addition to that, afford a robust risk management model.

Figures (2 and 3) show the values of the comparison matrix and the calculated values of priorities weights. The highest priority is for the supply chain perspective, which includes two types of risks: production risk and disruption risk with 24.2% of the influence. Followed by the internal and operational business process perspective with 18.4 % where the technical risk is the key risk in this perspective with 10.4%. Subsequently, the disruption risk with 9.4% and the lowest priority risk in this perspective is the "project neglect risk" with 2.5%.

Fig.2: Weights for each perspective and each risk indicators

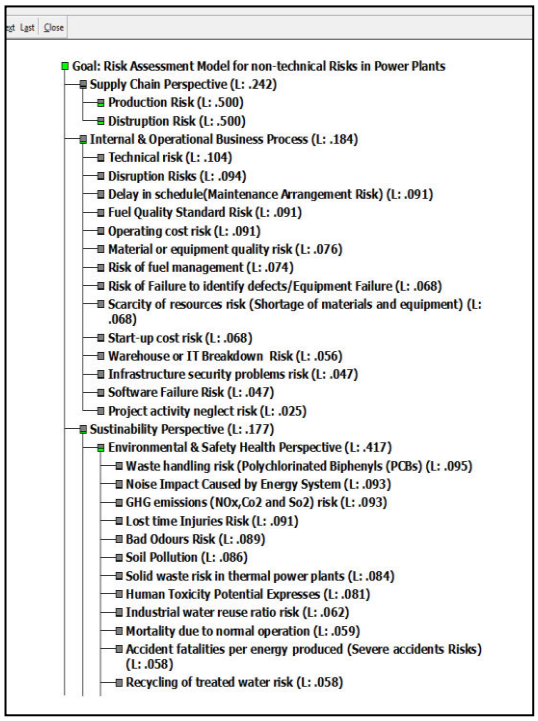
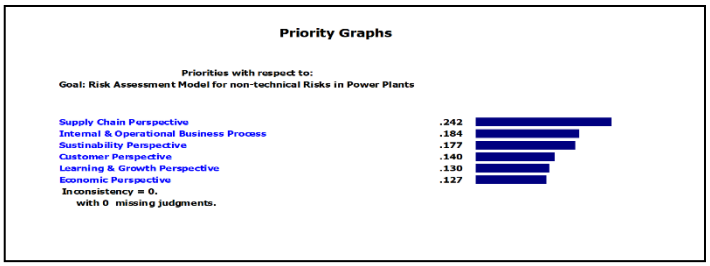


Fig.3: Summary of the AHP weights for the Six Risk Perspectives.



This BSC-AHP risk model will be validated in the next stage of building the System Dynamic Model (SD), a questionnaire will be distributed to experts from different departments at power plants in the Middle East and then a comparison will be executed between the results of the questionnaire and the results of the model.

VII. Conclusions:

The developed FMEA methodology that has been used in this research can boost effective decision-making about risks, improve power plants towards risk management, and assist the top management to have an acceptable and preferable understanding of the organisation than lower level managers do who are close more to the day-to-day (tactical plan) organisational operations. Additionally, the results of EWGM-RPN help in developing the AHP model by assigning the comparison importance across each risk indicator. Furthermore, the improved method overcomes some drawbacks in the traditional FMEA in simple way where this will provide more accurate, practical and reasonable results. The results of this study demonstrate that the supply chain risks perspective (production risks, disruption risks) is the keystone for the decision making process followed by internal and operational business process perspective.

The developed risk scorecard framework with six perspectives could be an effective tool for risk assessment, where the BSC help in understanding all the selected risk in the appropriate perspective while the AHP provides weights for each perspective and for each risk indicator.

As a whole, these results will be changed depending on power plant and the policy of the country. For example, some of these risks particularly, the economics risks are limited (ex. the power plants transactions in U.S. Dollar have negligible exchange risk since the currency is fixed compared with the U.S. Dollar). Similarly, the generating companies have not been exposed to credit risk because the only client of the company is the National Company in that country, as it is wholly owned by the government. Moreover, the supply risk has a high RPN value comparing with other risk categories and this is because the country depends on the imported fossil fuel to generate electricity (Central Electricity Generating Company/Jordan, 2016).

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