Risk Assessment of EPS in Building and Construction Projects: A New Technology in the Libyan Market

Mohamed A. Sherif
School of Engineering and Applied Science, Engineering Project Management Department
The Libyan Academy, Tripoli-Libya
awidat54@gmail.com

Saber Kh. Elmabrouk
Faculty of Engineering, University of Tripoli
Tripoli, Libya
s.elmabrouk@uot.edu.ly

Abdelwahed H. Elalem
School of Engineering and Applied Science, Engineering Project Management Department
The Libyan Academy, Tripoli-Libya
aelalem@ymail.com

Abstract
Expanded polystyrene (EPS) is a lightweight material that many people recognize as being used in packaging materials. EPS is an innovation building material that lends to design and structural integrity of many building projects. Nowadays, EPS became a powerful design element and an ideal choice for green building design, offering tangible environmental advantages that can maximize energy efficiency, provide improved indoor environmental quality and enhance durability. Recently, EPS is manufactured as a flame retardant grade, which reduces the risk of accidental fire. With all of the previous advantages of using EPS, there are still some risks associated with the utilization of this material in the construction sector, especially when it enters to the market as a new product. This study aims to assess the risks that could come up with the use of EPS material as a relatively new product in the Libyan construction sector. A total of 30 risks were identified and recognized into seven main categories; *resource*, *technical*, *economic*, *management*; *design*, *installation*, and *others.* The risk of "sudden change of foreign exchange rate" under the economic risks category, and "lack of training readily available" under the technical risks category were the most frequently mentioned risk factors.

Keywords
expanded polystyrene (EPS), risk assessment, risk management in construction projects, construction projects in Libya

1. Introduction:
Risk assessment and risk management have been established as a scientific area and have made important contributions to support the decision-making process. In recent years, many attempts have been made in developing a broader perspective on perception, assessment and risk management. However, many studies have been published dealing with different aspects of risk assessment and risk management in different scientific fields. For example, in 2015 Elkhawaldi and Elmabrouk showed that risk assessment has always been the most challenging part of the risk management process for aviation operations, and Elmhedwi; et al. (2015), noted that recently, instability and unrest in Libya have raised the issue of risk analysis to a very sensitive level that may affect any business activity, and this has placed more emphasis on identifying and assessing potential risks at a very early stage of any project, which is critical to planning the most appropriate strategies for reducing threats and exploiting opportunities. Thus, every organization is continuously exposed to an endless number of new or changing threats and vulnerabilities that may affect its operation or the fulfillment of its objectives. Identification, analysis and evaluation of these threats and vulnerabilities are the only way to understand and measure the impact of the risk involved and therefore to decide the appropriate measures and controls to manage them.

In highly competitive markets, the launch of new products with innovative strategic functions and performance is essential for the survival of companies and the factors required to achieve advantage in institutional competition. It is reported that the success rate of projects to develop new products, however, is very low. Around the world, nearly

© IEOM Society International

80% of new product manufacturer projects fail before completion. More than half of 20% of successful cases fail to return investment costs and become profitable. High costs and more time than expected were used to achieve project objectives (Coppendale, 1995, Cooper, 2003 and Ahn et al, 2008).

There have been many studies on risk analysis and management, but systematic research on how to build a risk management system is rare. In particular, there are few systematic studies on the establishment of risk management systems for the development of new products. This study aims to assess the risks that could come up with the introduction of expanded polystyrene (EPS) as a relatively new construction material for a new market (Libyan construction sector). Given a limited budget, needed to know the highest risk areas to focus improvement efforts. A brief research study provides of failure mode to allow the development team to quickly prioritize the highest risk subsystems and components in the registry plan. Once identified, the team will deal with it quickly and reduced the risk of reliability significantly.

2. Expanded Polystyrene (EPS); a brief overview

EPS is a lightweight plastic material that most people recognize as being used in packaging material. EPS is one of the most common lightweight building and construction materials used in many countries around the word, with this sector making up approximately 65% of all EPS use in Australia (Expanded Polystyrene Australia, EPSA, 2016). EPS offering excellent insulation and strength properties at a very light weight. When handled and installed correctly, it is safe, practical and cost effective, especially when taking into account its insulation properties over the life of a building.

The end product of the EPS is typically around 98% air and 2% polymer, consisting of small spheres in a closed cellular construction which gives it valuable characteristics for the building and construction industry, including being: (1) exceptionally cost effective and light weight construction material, (2) 100% recyclable, (3) versatile and easy to cut and mold for different purposes, (4) easy to install and maintain, (5) water resistant, (6) an excellent thermal insulator, (7) shock absorbent, (8) a high load-bearing material at low weight, (9) saving energy, (10) providing improved indoor environmental quality and enhancing durability, and (9) a good vapor, air and dust barrier. EPS is produced in a three-stage process: (1) *Pre-expansion*; steam causes the raw polystyrene beads to expand up to 50 times their original volume. (2) *Conditioning*; after expansion, the beads are then conditioned and undergo a maturing period in preparation for molding. (3) *Molding*; the beads are then placed within a mold and reheated with steam, expanding further to completely fill the mold and fuse together (Medne, 2010, Calbureanu et al, 2010 and Khole and Mohod, 2016)).

As construction material, EPS becomes an innovative building material that lends to the design and structural integrity of many building projects. Raj et al (2014) show that the unit weight of EPS embedded structure is up to 35% less than the conventional concrete structure and the pre-assembled units reduces the overall cost of structure significantly. Ngugi et al, (2017) noticed that the EPS was initially mainly used for insulation foam for closed cavity walls, roofs and floor insulation. Following continued research and innovation, EPS usage has extended in the building and construction industry in road construction, bridges, floatation, railway lines, public buildings, drainage facilities and family residences. EPS is a thermoplastic material manufactured from styrene monomer, using a polymerization process which produces translucent spherical beads of polystyrene

Nowadays, the EPS panels sandwiched between two mats of welded wire mesh. The mats of wire mesh are connected by thirty-three connectors per two meters realizing a 3D hyper static reinforcement steel. The panels are assembled at site then finished with concrete blasting or/and pouring on each side. Ede and Ogundira in 2014 carried out a research illustrating the application of this material in building and construction projects. They illustrator that the EPS used for building construction are of various types and sizes with the most common ones being for wall panels and for slab that are erected with steel meshes. The steel wire mesh serves as reinforcement. The EPS 3D reinforced wall system usually transfers shear and compression forces along the wall plane. The wall system is completed by applying concrete layers of acceptable thickness on both sides to perform the dual functions of protecting the reinforcements against corrosion and for transference of compressive forces. Typically, there are four types of EPS panels; single panel, double panel, high strength panel and roof panel.

However, in case of installation, the system needs a linear foundation that could be made using a continuous concrete footing or any type of foundation in accordance with the geotechnical characteristics of the terrain. Trace the position of the interior and exterior walls using a measure or similar tool. The anchor bars are usually inserted before pouring

© IEOM Society International

the foundation. Alternatively, it is possible to drill holes in the existing slab and then anchor the bars with an approved system. Due to its lightweight, a single operator can easily lift and place panels where necessary. There is another factor that contributes to saving labors compared to traditional techniques. The false frames are mounted in the openings cut according to the requirements that join the anchor steel with the steel wire mesh of the panel. Immediately after the placement of the panels, the perfect linearity and verticality of the walls is checked and ensured. A hot air gun or torch is used to create channels in the polystyrene for the placement of switch boxes, electrical conduits, cables, pipes, etc. Once the floor panels are placed, supported by the walls and from below, additional steel reinforcement is installed if necessary, then, the concrete is poured. The lattice girders are suitable for this application as reinforcement steel they will be incorporated in the intended locations on the floor panels. Both sides of the walls of single panel are sprayed with shotcrete and subsequently finished with plaster. Once the reinforcement steel is placed, proceed with the concrete is poured in the superior part. Finally, the finishing works are completed which include painting and other finishing touches.

3. EPS as a new product in Libyan construction market

In business and engineering, new product development is the term used to describe the complete process of bringing a new product to market. A product is a set of benefits offered for exchange and can be tangible or intangible. There are two parallel paths involved in the new product development process: one involves the idea generation, product design and detail engineering; the other involves market research and marketing analysis (Susterova et al, 2012). However, a large part of the risk for a new product depends on the marketing plan. For example, if your strategy is to sell a product to double the price of similar alternatives, the risk of failure is high. Your competitors will lower your sales and earnings. On the other hand, planning to sell your product at a very low price may be risky, if your prices are too low to cover costs, your business model will fail. If your product type has never been seen before, you will have little competition at first, but when your product turns out to be profitable, competitors will start organizing their own product campaigns. Therefore, controlling the risks of a new product depends to a large extent on developing a strategically sound and financially feasible marketing plan.

In Libya, there is poor and inadequate professional support in use of EPS material for construction. Most graduate students and practicing engineers are not conversant with this new building technologies and therefore often design housing using the traditional technology. There lacks research information on the acceptability of use of EPS materials by professionals in Libyan's construction industry. The slow uptake of EPS as a construction material in Libya is has further attributed to lack of awareness of EPS existence in the country, lack on readily information on EPS's economic, environmental and social benefits, lack of trained readily available EPS artisan, lack of design manual for high-rise buildings using EPS and high transport cost for projects located far from Tripoli. There lacks an approved quality standard on use of EPS in Libya. Standardization of EPS to protect consumers is required to put in place safety requirements technology for manufacturing the prefabricated EPS materials is quite new to the Libya Bureau of Standards. Hence, many developers are not aware of availability of alternative construction technology. EPS technology need to be contextualized in Libya to generate the expected cost reduction. Accordingly, these and other factors mean that the process of introducing this new product into the Libyan markets face great challenges and is not an easy task.

4. Project risk management

Project risk is an event, feature, activity, or uncertain situation that can have a positive or negative impact on project results. Risk management and opportunity management are formally identified and evaluated. Specifically, risk is the investment opportunity will perform different than expected. This means both better or worse performance than expected. Thus, new business is a risk and this risk, certainly, can be managed. The main objective of threat management and safekeeping risks is to provide maximum protection to this business while providing ease of use. Risks have to be identified, analyzed and reduced to the minimum. However, risk management techniques have been described in detail by many authors. A typical risk management process includes the following key steps: (1) *Risk identification*; (2) *Risk assessment*; (3) *Risk mitigation*; and (4) *Risk monitoring* (Elkhawaldi and Elmabrouk, 2015, and Elmhedwi, 2015). Nonetheless, risk assessment is a systematic process for identifying and evaluating risks that could affect the achievement of project objectives.

In general, most organizations worldwide suffer from weaknesses that can directly affect their business process. Thus, risk assessment is the method used to deal with threats, vulnerabilities and loss effects. Risk identification is the first and perhaps the most important step in the risk management process, as it attempts to identify the source and type of

© IEOM Society International

risks. It includes the recognition of the possible conditions of risk events in a certain project. Hereby, the authors have adopted three ways to detect potential risks: i) brainstorming - a technique used to generate and collect ideas related to the project with some specialized engineers. In this way, a list of potential risks that are believed to occur during the process of using EPS as a new product in construction projects has been identified. (ii) Interviews: This is a formal or informal approach to extract information from experts when meeting with them or through some means of other communication. The authors conducted a series of interviews with some construction experts; and (iii) Search the Internet for some international companies specialized in this field.

Risk assessment is conducted in two significant ways; qualitative and quantitative risk analysis. Usually, the quantitative analysis follows the qualitative analysis, but the two processes can be conducted simultaneously. Quantitative risk management in project management is the process of converting the impact of risk on the project into numerical terms (calculate the risk degree). Risk degree denoting the impacts of risk factors; $R = P \times I$, where R is risk degree, P is the probability of risk occurrence and I is risk factor impact. The likelihood of occurrence (P) can vary from just over 0% to just under 100%. It cannot be exactly 100%, because then it would be certainty, not a risk, nor can it be exactly 0%, or it would not be a risk. Risks, by their very nature, always have a negative impact. Whereas, in qualitative assessment, the risk probability and risk impact are measured using a relative scale. Table 1 and 2 are an example of the definition of probability and impact scale in qualitative analysis.

With the preparation of quantitative and qualitative risk scale, a risk assessment matrix can be created to help for categorize the risk level for each risk event. The risk assessment matrix allows for potential risks in 2D as shown in Fig. 1. The probability of a risk occurring is represented in one axis of the matrix and the impact in the other. The risk matrix grid provides a quick and clear view of the priority to be given to each one. Then, you can decide which resources you will allocate to manage that particular risk. A risk assessment matrix type 5×5 was applied here with risks severities ranges from *critical* through to *high*, *medium*, and *low*. This illustrated in Fig. 1.

Table 1- An example likelihood scale definition

Rating	Likelihood	Description
1	Very Low	Highly unlikely to occur. May occur in exceptional situations.
2	Low	Most likely will not occur. Infrequent occurrence in past projects.
3	Moderate	Possible to occur.
4	High	Likely to occur. Has occurred in past projects.
5	Very High	Highly likely to occur. Has occurred in past projects and conditions exist for it to occur on this project.

Table 2- An example impact scale definition

Rating	**Impact**	Potential impact in terms of the objectives
1	Negligible	Very small impact, rectified by normal processes
2	Minor	Easily remedied, with some effort the objectives can be achieved
3	Moderate	Some objectives affected, considerable effort to rectify
4	Major	most objectives threatened
5	Catastrophic	most objectives may not be achieved

The final stage of the risk assessment is to combine all previously identified risks and entered them in the risk register. According to ISO 73:2009 Risk management vocabulary (International Organization for Standardization, ISO website) defines a risk register to be a "record of information about identified risks". However, there is no standard list of components that should be included in the risk register. The Project Management Institute Body of Knowledge (PMBOK) and PRINCE2 among other organizations make recommendations for risk register contents, but they are not set in stone.

A total of 30 risks was identified and recognized into seven main categories; (1) resource risks, (2) technical risks, (3) economic risks, (4) management risks; (5) design risks, (6) installation risks, and (7) other risks. The details of these risks are illustrated in the risk register (Table 3). Once the risks and probabilities are determined, the risk score can be calculated. Risk score is detailed in Table 1. The probability (p) and impact (I) illustrate a risk rating assignment for individual risk factors in the identified risks categories. Under the economic risks category and technical risks category, sudden change of foreign exchange rate (E1) and lack of training readily available in using EPS (T3) were the most frequently mentioned risk factors. Assessment of project level risk factors is presented in Fig. 2. Risks with high degree (critical risks) are required further analysis, including quantification, and aggressive risk management.

Risk Assessment Matrix Grid 5×5						
Very high	Likelihood	5	10	15	20	25
High		4	8	12	16	20
Moderate		3	6	9	12	15
Low		2	4	6	8	10
Very low		1	2	3	4	5
		Impact				
		Negligible	Minor	Moderate	Major	Catastrophic

- Critical Risk
- High Risk
- Medium Risk
- Low Risk

Fig. 1- Risk assessment matrix

Table 3- Classification of risk factors by category

Category	**Risk #**	**Risk Description**	***P***	***I***	***R***
Resource Risks	R1	Critical resources may not be available when required	4	5	20
Technical Risks	T1	Failure to effectively mix internal and external expertise	4	4	16
	T2	Shortage of qualified workers in this type of construction	4	5	20
	T3	Lack of training readily available in using EPS	5	5	25
	T4	No technical standard for EPS safety and manufacturing	5	3	15
	T5	Absence of civil engineers specializing in planning, design and supervision of this type of construction	5	3	15
	T6	No quality standard on the use of EPS	5	3	15
	T7	Lack of integration between process and planning	3	3	9
	T8	Inexperienced workforce and staff turnover	4	3	12
Economic Risks	E1	Sudden change of foreign exchange rate	5	5	25
Management Risks	M1	Weak support from stakeholders in the use of EPS as construction materials	4	4	16
	M2	Lack of available project management skill	4	3	12
	M3	Change in organizational management	4	2	8
	M4	Team members not familiar with the task(s) being automated	4	2	8
	M5	Failure to comply with contractual quality requirements	4	4	16
Design Risks	D1	No design guide for using EPS in building and construction especially in high-rise buildings	5	3	15
	D2	No design manual for using EPS in building and construction	5	3	15
	D3	Design errors and omissions	3	4	12
	D4	Stakeholders request late changes	4	4	16
	D5	Failure to carry out the works in accordance with the contract	4	3	12
Installation Risks	I1	Cut parts of steel wire mesh to place switch boxes, electrical ducts, tubes, etc. this may weaken the wall	4	4	16
	I2	Forgetting to place parts of the drainage system and electrical works	3	5	15
	I3	Errors in cutting and molding	2	5	10
	I4	Errors due to improper use of the hot air gun	2	4	8
Other Risks	O1	Transport cost for sites far away from Tripoli (factory)	4	5	20
	O2	Not accepting people to use EPS in building	4	5	20
	O3	Construction cost overruns	3	5	15
	O4	Technology changes	4	2	8
	O5	Fire hazards	3	4	12
	O6	Public objections	4	5	20

© IEOM Society International

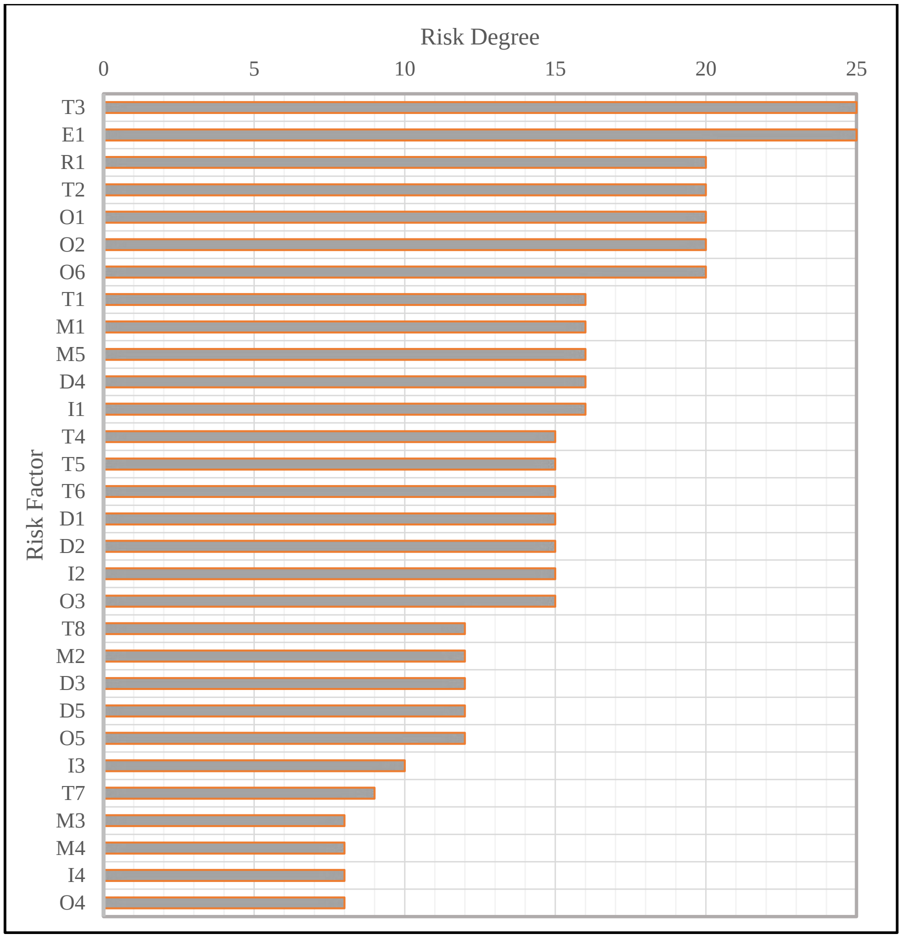

Fig. 2- Assessment of project level risk factors

5. Conclusion

Recently, EPS has become an innovative building material that lends to the design and structural integrity of many building and construction projects. In Libya, there is a poor and an inadequate professional support in the use of EPS material for construction. Most graduate students and practicing engineers are not conversant with this new building technologies and therefore often design housing using the traditional technology. There lacks research information on the acceptability of use of EPS materials by professionals in Libyan's construction industry. The slow uptake of EPS as a construction material in Libya is has further attributed to lack of awareness of EPS existence in the market. This study aims to assist the risks that could come up with the use of EPS material as a relatively new product in the Libyan construction sector. A total of 30 risks was identified and recognized into seven main categories; (1) resource risks, (2) technical risks, (3) economic risks, (4) management risks; (5) design risks, (6) installation risks, and (7) other risks. Under the economic risks category, the risk of sudden change of foreign exchange rate, and the risk of lack of training readily available in using ESP in building and construction projects under technical risks category were the most frequently mentioned risk factors.

6. References

Ahn, J. O. Jeung, H. S. Kim, J. S. and Choi, H. G. (2008) A framework for managing risks on concurrent engineering basis. Proceedings of the IEEE International Conference on Management of Innovation and Technology.

Calbureanu M. X., Albota, E. Tut, D. Tutunea, D. Dumitru S., Malciu R. and Dima, A. (2010) Contributions above the dew-point problem in civil building EPS insulated walls modelling with finite element the convective heat transfer. International Journal of Mechanics., vol. 4, no. 3, pp. 53-62

Cooper, L. P. (2003) A research agenda to reduce risk in new product development through knowledge management: a practitioner perspective. Journal of Engineering and Technology Management, Coppendale, J. (1995) Manage risk in product and process development and avoid unpleasant surprises. Journal of Engineering Management, Vol. 5, pp. 33-38.

Ede, A. N. and Ogundiran, A. (2014) Thermal Behaviour and Admissible Compressive Strength of Expanded Polystyrene Wall Panels of Varying Thickness, Current Trends in Technology and Science, vol. 3, no. 2, pp. 110 -117.

Elkhweldi, Mansour A. and Elmabrouk Saber Kh. (2015) Aviation risk management strategies: Case study. 2015 International Conference on Industrial Engineering and Operations Management (IEOM), IEEE Conference Publications.

Elmhedwi, Tawfik R. Elmabrouk, Saber Kh. And Sherif, Mohamed A. (2015) Practical risk management plan of Wi-Fi network deployment; case study. International Conference on Industrial Engineering and Operations Management (IEOM), IEEE Conference Publications.

Expanded Polystyrene Australia, EPSA (2016) www.epsa.org.au

International Organization for Standardization. ISO Guide 73:2009 Risk Management-Vocabulary http://www.iso.org/iso/catalogue_detail?csnumber=44651

Khole, P. V. and Mohod, M. V. (2016) Application of Smart Materials in Civil Engineering for Better Tomorrows: A Review. International Journal of Engineering Research, vol. 5, no. Special 3, pp. 665-668.

Medne, O. (2010) Research on Expanded Polystyrene Product Manufacturing Process, Riga Technical University, Riga,

Ngugi, H.N, Kaluli, J.W and Abiero-Gariy, Z. (2017) use of expanded polystyrene technology and materials recycling for building construction in Kenya. American Journal of Engineering and Technology Management 2(5): 64-71

Raj, R. Nayak, M. K. Akbari, M. A. and Saha, P. (2014) Prospects of Expanded Polystyrene Sheet as Green Building Material. International Journal of Civil Engineering Research. Volume 5, Number 2 (2014, vol. 5, no. 2, pp. 145-150

Susterova, M. Lavin, J. and Riives, J. (2012) Risk Management in Product Development Process. Annals of DAAAM for 2012 & Proceedings of the 23rd International DAAAM Symposium, Volume 23, No.1, ISSN 2304-1382. Published by DAAAM International, Vienna, Austria, EU

Biographies

Mohamed A. Sherif is the head of the Engineering Project Management Department at the Libyan Academy of post graduate, School of Applied Science and Engineering, Tripoli, Libya. He received his PhD in construction management from Loughborough University, UK and his BSc. in Civil Engineering from San Diego State University. His research interest includes; improving planning in construction projects, productivity improving construction performance.

Saber Kh. Elmabrouk received the Ph.D. degree in Petroleum Engineering from the prestigious University of Regina, Canada. Prior to his Ph.D. he had earned his Master and Bachelor degree, both, in Petroleum Engineering from University of Tripoli, Libya. Currently, Dr. Saber is assistant professor at University of Tripoli, Petroleum Engineering Department. Also, he is an adjunct faculty at The Libyan Academy, Engineering Project Management Department, School of Applied Science and Engineering, Tripoli, Libya. Moreover, he is a person of interest, grad supervisor at Schulich School of Engineering, Chemical and Petroleum Engineering, University of Calgary, Canada. His teaching and research career spans over 20 years. His research interests include reservoir management, artificial intelligence techniques, modeling, data mining and uncertainty and risk management.

Abdelwahed H. Elalem graduated in 2015 from the Department of Civil Engineering, Faculty of Engineering, University of Tripoli, Tripoli, Libya. Currently, Mr. Elalem graduate student in the Libyan Academy, Department of Engineering Project Management, School of Applied Sciences and Engineering, Tripoli, Libya. His research interest includes risk management and operations management.

© IEOM Society International