Use of Fractional Factorial Design and AHP to Determining the Best Marketing Strategy for a Lubricant Company

Anas Al-Dawalibi and Ibrahim H. Al-Dali
Systems Engineering Department
King Fahd University of Petroleum and Minerals
Dhahran, Saudi Arabia
g201702790@kfupm.edu.sa , g200256480@kfupm.edu.sa

Bandar A. Alkhayyal
Department of Engineering Management,
College of Engineering,
Prince Sultan University,
Riyadh, Saudi Arabia
balkhayyal@psu.edu.sa

Abstract
A lubricant company marketing team facing a series of problem to identify the best marketing strategy for certain type of lubrication product because the marketing plan involves a large number of factors that can affect the sales revenue response. So 2^{K-P} Fractional Factorials has been used as screening experiment and the most important factors that has main effect to response the sales revenue has been identified. Then further decision-making technique has been introduced to compare the selecting factors using analytic hierarchy process technique. AHP will provides a comprehensive and rational framework for structuring decisions criterial to each main factor where it provides the best factor or marketing strategy that can increase the sales revenue for the company.

Keywords
Fractional Factorial Design, Marketing Strategy, Screening Experiment, MCDM, and AHP

1. Introduction and Statement of the problem
The lubricant company is interested to select the best market strategy to identify the factors which have the most major effect in the sales revenue then selecting the best factor among major effects using multi criterial decision technique (MCDM). The objective is to use the fractional factorial deign as screening experiment to determine the most effective factors form the following: TV adv, Saudi football league adv boards, social interaction, free of charge oil, radio adv, packaging, and size of the carton. The company does not have enough resources to run 27=128 experiments in different locations as it will be too costly for the company and it needs a lot of manpower to perform a full factorial experiment using only two levels of each factor. So according to that it is decided that a screening experiment using fractional factorial deign will be performed in an effort to identify the more important factors. After finding most important factors an analytic hierarchy process technique (AHP) will be used to select the best market strategy. Table 1 shows the levels for each factor for the screening process.

The company decides to test the sale and 17 different locations are available to run the experiments, but 8 locations of the 17 will be selected at random and then randomly assigned the treatment combinations indicated in Table 2. In these situations, often as many as P-1 variables will be examined using only P experimental runs which is 8 runs in our example.

Table 1. Factor and levels for the marketing experiment

Symbol	***Factor***	***Low Level***	***High Level***
A	TV adv	No adv	Adv
B	Football league adv boards	No adv	Adv
C	Social Interaction	No Interaction	Interaction
D	Free of charge (FOC) Oli	No FOC	FOC
E	Radio adv	No adv	Adv
F	Packging	Traditional	Innovation
G	Size of the carton	12 botteel per carton	24 bottel per carton

It appears that screening experiments should be useful in marketing strategy selection because most marketing situations involve a large number of factors especially when it comes for lubrication oils where lubricant company has many alternatives factors to choose from that can have a main effect in sales response. The marketing team decides to perform the screening experiment without replication as it will consume a huge amount of the company resources and, therefore, have no estimate of experimental error.

Table 2. Levels for factors to be used in each sales area

	Factors							
Sales Area	**A**	**B**	**C**	**D=AB**	**E=AC**	**F=BC**	**G=ABC**	**Sales 1000 (SR)/week**
1	-	-	-	+	+	+	-	155
2	+	-	-	-	-	+	+	675
3	-	+	-	-	+	-	+	410
4	+	+	-	+	-	-	-	513
5	-	-	+	+	-	-	+	575
6	+	-	+	-	+	-	-	1050
7	-	+	+	-	-	+	-	750
8	+	+	+	+	+	+	+	1020

2. Literature Review

The design of experiments is one of the most used techniques that is implemented by companies for various uses that helps them with maximizing profits while minimizing the costs. However, it has marked a late entry into the world of marketing where it has become the center of attention due to its severe advantages in comparison to its side effects. This section is intended to cover all the research that has been conducted in the marketing sector and the use of design of experiments that encompasses factorial design and fractional factorial design with the intent to enhance it. In the Holland and Craven (1973), particular emphasis has been placed on the fact how fractional factorial design is more advantageous to a business in specific correspondence to marketing as with the traditional factorial design. An example has been elaborated in detail that clearly narrates that a fractional factorial experiment will be several times more beneficial to a company that is advertising for its product which in this case is a candy bar. On the other hand, it also states the areas where it is better to persist with traditional factorial design methods when the fractional factorial design does not bring about as many benefits as needed. In the Kuhfield (1994), the use of design efficient experimental

designs has been studied in the field of orthogonal arrays, non-orthogonal designs, relative efficiency and non-orthogonal design algorithms. A design is created for a choice study with asymmetry and interaction in addition to a conjoint study with blocks and aggregate interactions. On the other hand, it also states the areas where it is better to persist with traditional factorial design methods when the fractional factorial design does not bring about as many benefits as needed. In the kuhfield (1994), the use of design efficient experimental designs has been studied in the field of orthogonal arrays, non-orthogonal designs, relative efficiency and non-orthogonal design algorithms. A design is created for a choice study with asymmetry and interaction in addition to a conjoint study with blocks and aggregate interactions. It has been just recently that people in the marketing industry have grasped the great importance of using experimental design to improve the profit, marketing and the advertising of their specific products. These new statistical tools have provided them with a whole new dimension to evaluate the factors that will optimize the sales of the product they are marketing in the industry. In the Bell, Ledolter, and Swersey (2006) paper, it is clearly illustrated and proven how the use of well adapted factorial experiments that have been thoroughly designed is better to a company in the case of marketing than simply using the traditional one factor at a time factorial design experiment.
The design of experiment method has been commonly used in the area of manufacturing but rarely used in the service industry. A two-level fractional factorial design of 16 runs is used by Ledolter, and Swersey (2006) to increase the direct mail response of Mother Jones Magazine which has 7 factors influencing its response. This is in complete contrast to the traditional method where factors are changed only one at a time. The design is compared to other potential designs with the main focus on the factors to identify the interactions.

3. Result and Data Analysis

Minitab has been used for data analysis and comparison for solving table 2. And all the results will illustrate in tables and graphs. From table 3 we can see that factor A (TV adv) and factor C (Social Interaction) have a significant effect on our response to the sales revenue. As replication is not performed on the screening experiment, therefore, have no estimate of experimental error. As for the Data Analysis, Minitab again was used in the construction of graphs and plots that illustrated the significance of specific main factors and interactions that would have an effect on the sales revenue of the company.

To begin with, the pareto chart or the histogram was obtained from Minitab as shown in Figure 1. Where we can find that the critical value is 299.2. As it can be observed from the figure, only Factors A and C exceeded the critical value by having an effect value of 342 and 410.5 respectively. This means that only these 2 Factors were the main effects of this problem that had a significance on the response and that all the other factors were Insignificant.

Table 3. Shows the main effect and sum of squares

Factor	Main Effect	Sum of Squares	Percent Contribution %
A	342.00	233928	**36.89**
B	59.50	7081	**1.12**
C	410.50	337020	**53.14**
D	-155.50	48361	**7.63**
E	30.50	1860	**0.29**
F	13.00	338	**0.05**
G	53.00	5618	**0.90**
	SSTotal	**634206**	

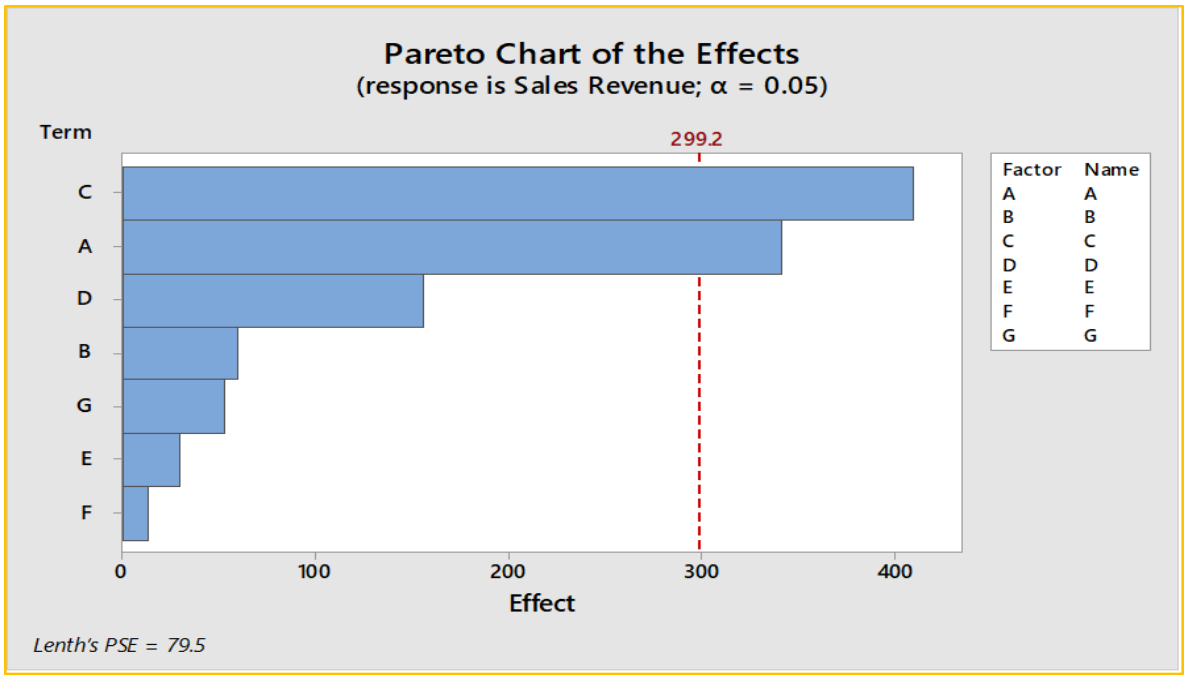

Figure 1. Name of the figure

Another aspect of the Problem that we were interested in was the plots showing the effect of the Individual Factors on the response being the revenue. Figure 2 illustrates the Revenue when there is a change in the level of each Factor. The plots of Factor A and Factor C affirm the fact that they have significant positive effect on the model response whereas Factor D has a negative response on the revenue. The reason being for this interesting observation is that providing the product free of charge will incur the company a loss and provide the customers with an incentive to fulfill their demand without having to purchase the product itself. A really clear. As for the remaining plots, the rest of the plots were not having any significant effect on the response along with Factor D.

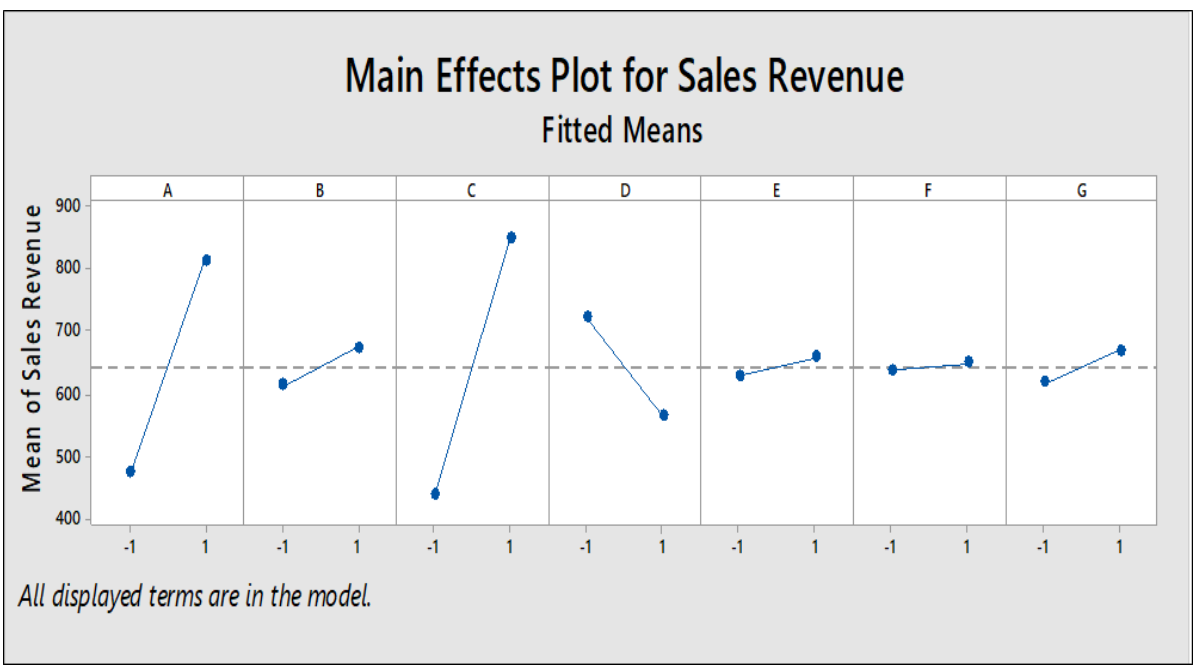

Figure 2. Plots showing the revenue for change in level of each factor

Since we were interested in discussing the interaction between different factors and how it was going to have an effect on the revenue, Figure 3 below shows the multiple plots obtained from Minitab showing the interaction between different combinations of all the Factors. Taking the plot of the graph A*C, it can be clearly depicted that there is no interaction between these 2 factors whatsoever. The factor A is represented by the X-Axis where Factor C is planted onto the graph by the use of 2 curves, red symbolizing the positive level of C and blue the negative level of C. The optimum level of revenue is derived in the case where the level of Factor A is high in conjunction with the level of Factor C being high. This plot is in complete contrast with that of A*B where there is a definite interaction and the optimum response occurs when A has a high level and B has a low level.

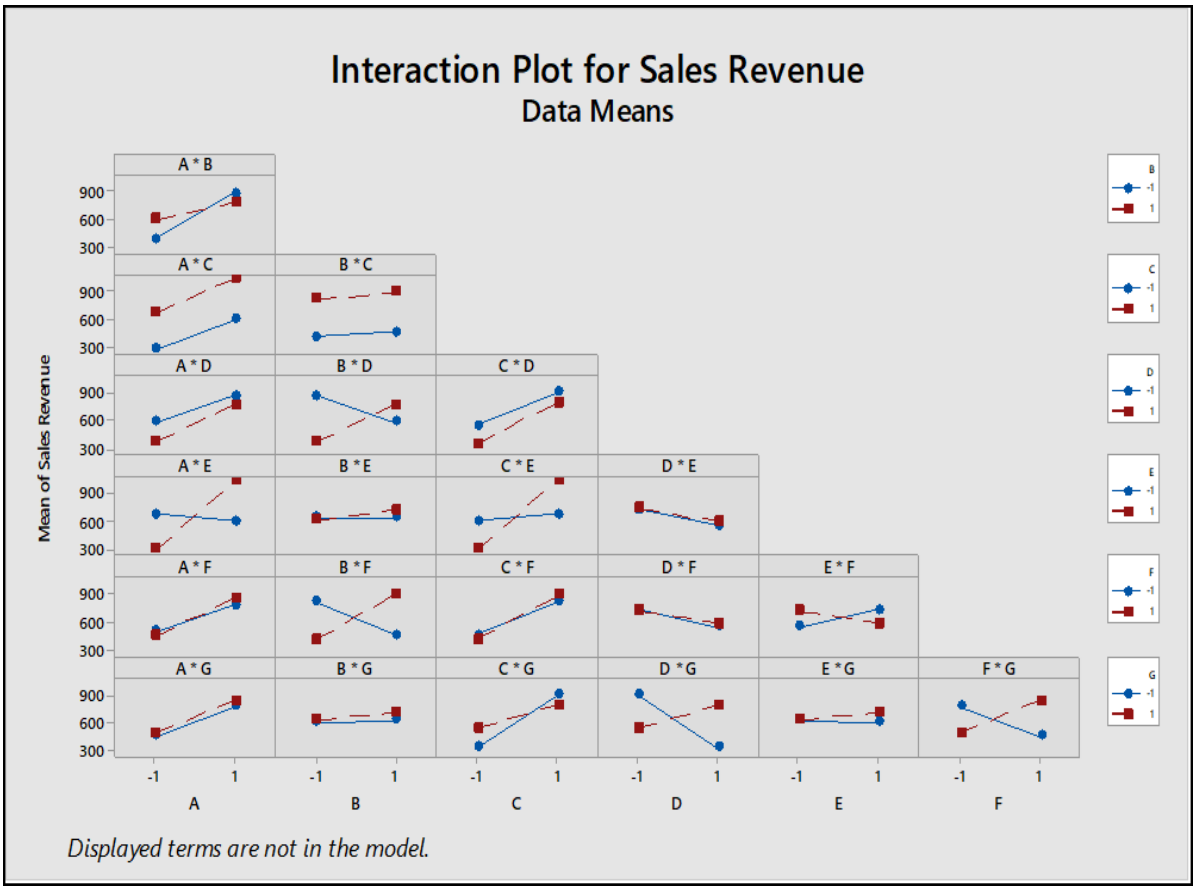

Figure 3. Plots depicting the interaction between Factors and effect on Revenue

All of this brings us to our final model that is represented in the form of regression equations. Firstly, the regression equation for all factors is the following:
Y= 643.5+171A+29.75B+205.3C-77.75D+15.25E+6.5F+26.5G

The value of 643.5 is found by taking the average of the sales column from Table 2 that is (155 + 675 + 410 + 513 + 575 +1050 + 750 + 1020) / 8 = 643.5. The coefficient of all the factors in the regression model above can be obtained by dividing the effect estimate of each factor by 2 since we have 2 levels for each Factor. Now, writing the regression model taking into consideration only the significant factors provides us the following with Y denoting the sales revenue of the problem:
Y= 643.5+171A+205.3C

From the Data Analysis, it can be concluded that Factor A (i.e. TV advertisement) and Factor B (i.e. Social Interaction) are the only factors having a true effect on the revenue from selling this product. All of the Interactions of Factors in addition to the remaining Factors are insignificant in the context of adding a value to the company's objective of optimizing its revenue.

4. AHP for Determining the Best Marketing Strategy

This part is a decision-making model optimization of a lubricants company to identify the best marketing strategy using AHP approach and after using fractional factorial design as screening experiment where we eliminate factors that do not have any significant effect on response (sales revenue). Below are the stages to be followed to come up with best marketing strategy and select the best strategy form the remaining strategies which are in our case factors A and C:

i. **Data Gathering and Criteria Definition:** all related data of sales volume, demand, costs...etc. are gathered along with criteria definition
ii. **Criteria Weights Determination:** stakeholders' input on the criteria weights to be collected and processed
iii. **Development and Process of MCDM Model:** a MCDM model to be built and solved for best setup based on the inputs from previous stage
iv. **Best Marketing Sourcing Alternative Selection:** the best marketing sourcing plan will be chosen in this stage
v. **Consistency Check and Best Setup Finalization:** this stage focuses on data consistency check and final setup recommendation for decision maker

5. Model Data and Parameters

The company's marketing team is asked to set main decision-making criteria of the model along with their respective weights. This exercise is conducted via direct meeting group discussion and below table shows the outcome. Each strategy will be examined using several, multiple criteria that have been provided by the company management along with their relative weights to be taken into account in the evaluation process. These criteria are Cost, Coverage, Interaction and Return-On-Investment (ROI). Table 4 shows criteria and their definitions as stated by marketing team.

Table 4. Model decision making criteria definitions

Criterion	Definition
Cost	Total expenses associated with each type of marketing strategy; including both fixed and variable costs.
Coverage	It is a measure of spread and geographical coverage of receivers that each marketing strategy can reach
Interaction	It is the level of reaction that each marketing strategy can result in after its deployment; How customers are going to perceive and interact with the content of each marketing strategy
ROI	ROI is a quantification of how much return or benefit that each marketing strategy can bring to the overall business once effectively applied. It is a cost: benefit analysis tool

Relative weights of decision-making criteria with respect to each other is shown in the table 5. Associated normalized matrix will be calculated also to determine the weighted score of each criterion to be used in related AHP model.

Table 5: Model Decision Making Criteria and Relative Scores

Criteria	Cost	Coverage	Interaction	ROI
Cost	1	1.5	2	0.85
Coverage	0.667	1	0.75	0.35
Interaction	0.5	1.33	1	0.9
ROI	1.18	2.86	1.11	1
Sum	**3.34**	**6.69**	**4.86**	**3.10**

Now; the two shortlisted marketing strategies will be evaluated versus each one of the decision criteria tables 6,7,8 and 9 shows the results.

Table 6: Evaluating marketing strategies compering to cost

Cost	TV	Soc. Comm.	Raw Sum	N. Raw Sum
TV	1	0.33	1.33	0.25
Soc. Comm.	3.03	1	4.03	0.75
Sum	4.03	1.33	5.36	1.00

Table 7: Evaluating marketing strategies compering to coverage

Coverage	TV	Soc. Comm.	Raw Sum	N. Raw Sum
TV	1	2.50	3.50	0.71
Soc. Comm.	0.4	1	1.4	0.29
Sum	1.40	3.50	4.90	1.00

Table 8: Evaluating marketing strategies compering to interaction

Interaction	TV	Soc. Comm.	Raw Sum	N. Raw Sum
TV	1	0.35	1.35	0.26
Soc. Comm.	2.86	1	3.86	0.74
Sum	3.86	1.35	5.21	1.00

Table 9: Evaluating marketing strategies compering to ROI

ROI	TV	Soc. Comm.	Raw Sum	N. Raw Sum
TV	1	0.25	1.25	0.20
Soc. Comm.	4	1	5	0.8
Sum	5.00	1.25	6.25	1.00

Now, using the above 4 metrics, an AHP model will be developed for each marketing strategy and the composite weights for the associated two options will be calculated using these formulas where applicable.

$$\text{Weight(TV Advertisement)} = \sum_{i=1}^{4} (P_i P_{TV_i})$$

$$\text{Weight(Social Networking)} = \sum_{i=1}^{4} (P_i P_{SN_i})$$

Best Marketing Strategy

Criteria	Cost *	Coverage	Interaction	ROI
Weight	30%	15%	21%	33%
TV	25%	71%	26%	20%
Social Networking	75%	29%	74%	80%

TV	**30.21%**
Social Networking	**68.79%**

Figure 4. Shows the AHP structure

Figure 4 shows the AHP structure and it conclude that the "Social Networking" is best option for the two available strategies.

6. Conclusion

After performing the data analysis in identifying the significant factors and screening out the insignificant factors, we found that factors A and C were the ones that were significant with the help of use of Minitab. This data that was derived was further analyzed with the assistance of AHP technique to bring us to our final most important conclusion that factor C was the most important Factor. In terms of the marketing strategy, it is thus proved that social networking which is factor C, is the most pivotal to the company in terms of increasing its revenue from the sale of its product.

Acknowledgements

The researchers deeply appreciate Prince Sultan University and King Fahd University of Petroleum and Minerals for supporting this project.

References

Holland, P. and Carvens, A. (1973), "Fractional Factorial Experimental Designs in Marketing Research," Journal of Marketing Research, 270–276.

Kuhfeld, W. F., R. D. Tobias and M. Garratt: 1994., Efficient experimental designs with marketing research applications, *Journal of Marketing Research 31, pp. 547–557.*

Bell, G. H., Ledolter, J., & Swersey, A. J. (2006)., Experimental design on the front lines of marketing: testing new ideas to increase direct mail sales. *International Journal of Research in Marketing*, 23(3), 309-319

Ledolter, J. and Swersey, A., Using a fractional factorial design to increase direct mail response at Mother Jones magazine, *Quality Engineering*, 2006, 18, 469–475.

Biography

Anas AL-Dawalibi is MSc Student in industrial Systems Engineer at KFUPM. He received his B.S. in Production and Manufacturing Engineering Management from Prince Sultan University. His research interests are: Mathematical modeling, Optimization of quality systems, Maintenance engineering, and applications of Markov Decision Processes.

Dr. Bandar A. Alkhayyal is an Assistant Professor and the Director of the Master Program in the College of Engineering at Prince Sultan University (PSU), Riyadh, Saudi Arabia. Dr. Alkhayyal received his B.S. degree in Computer Science with a minor in Industrial Engineering from the Eastern Michigan University, Ypsilanti, Michigan, USA, in June 2010. December 2011, he received his M.S. degree in Engineering Management specializing in Project

Management from the same school in Michigan, and in May 2013 he received his M.S. degree in Industrial Engineering from New Mexico State University, Las Cruces, New Mexico, USA, later he earned his PhD degree in Industrial Engineering specializing in Supply Chain Engineering and Logistics from Northeastern University, Boston, USA on December 2016. Dr. Alkhayyal has certifications in Project MGMT, Lean Six Sigma Green Belt, Lean Enterprise Systems, and Lean Concepts and Applications.

His research interests are in the areas of environmentally conscious manufacturing, product recovery, reverse logistics, closed-loop supply chains (CLSC), sustainable operations and sustainability, modeling with applications in CLSC and multiple lifecycle products, environmental engineering and sustainability, life cycle assessment, and energy efficiency and emission modeling. He has co-authored several technical papers published in journals and presented at various national and international conferences, and also working as a reviewer for professional journals.

Dr. Alkhayyal is teaching undergraduate and graduate courses on PSU, on Supply Chain, Logistics, Project MGMT, and Quality. Dr. Alkhayyal is the Faculty Advisor of PSU-IEOM Student Chapter, and member of Scientific and Technical Committees in supply chain conferences. Dr. Alkhayyal is the conference chair for 1st GCC International Conference on Industrial Engineering and Operations Management which will be on November 2019.