

## **Development of a Design Division for an Industry: A Capstone Project in a Master's of Engineering Management Program**

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Salah Al Omari is an associate professor at the department of mechanical engineering at UAE university. He earned his PhD from the Technical University in Aachen in Germany (RWTH-Aachen) in 1997. After that he worked for Mitsubishi Electric in Japan as a researcher at the R&D Center in Osaka. In 2000 he joined UAE University as assistant professor at the department of Mechanical Engineering. Salah Al Omari conducts research in the thermofluids areas particularly enhanced heat transfer, renewable energy, and combustion. . He published over 30 publications in reputable international journals and a about a similar number of international conferences publications. Recently, Al Omari got interested and involved in research in the area of engineering education. Salah Al Omari taught a large number of engineering courses both at the undergraduate and the graduate levels. He served as well as committee head for international (ABET) and national accreditation of the ME program at UAEU, for a number of consecutive accreditation cycles.

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Mrs. Aysha Abboud Shaikh Alameri graduated in Mechanical Engineering from the United Arab Emirates University in January 2013. Soon afterwards she joined Strata Manufacturing PJSC in Al Ain, UAE as an aerospace composites design engineer. Aysha worked in several different projects for Boeing and Airbus parts. She was an active member in the A350 project team to establish a process which generates high quality composite manufacturing data. She was a key member in the SDP1 Strata Design Project 1 that followed the design process from concept to final design review by creating the ply definition and the solid model. Aysha completed her Master of Engineering Management Degree from UAE University in February 2018. Aysha's interest is in the design process for composite components.

# **Development of a Design Division for an Industry: A Capstone Project in a Master of Engineering Management Program**

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## **Abstract:**

This paper describes the Capstone project undertaken in the Master of Engineering Management program at United Arab Emirates University. It divides the course into two parts: in the first part the students were trained to gain the diagnosis ability through the case study method. In the second part the students engage in a project where they evaluate and propose improved solutions to existing divisions or companies or design an administrative system for engineering divisions or companies. A group of students engaged themselves into forming a design division for a high-tech composite manufacturing company. They achieved this by establishing a hypothetical model of a design division and used the model for the specified company. The feedbacks from students suggest that the case study method showed them how to use the knowledge acquired through the taught courses in solving real-life problems.

## **1 Introduction**

Investigating what is typically involved in the Engineering Management (EM) master's degrees as offered by the larger programs, Peterson and Humble [1] identified 28 topics or courses. Since all 28 topics cannot be included in any single program the universities choose the topics in accordance to the requirements of their constituencies. Engineering Management is the process of planning, organising, staffing, leading and influencing people, and controlling activities, which have a 'Technological Component' [2]. Whatever the choice of the courses, the aim is to build the ability to combine management skills with technical expertise in coordinating work in various technical fields such as product design, development, and manufacturing. Capstone projects in a Master of Engineering Management program are therefore unique and are aimed to provide students with a learning experience on how to use their knowledge to solve a real life problem. In this paper we specifically elaborate on the Master of Engineering Management (MEM) program at United Arab Emirates University. The EM program at United Arab Emirates University was started in 2006. It consists of ten three-credit hour courses and a Capstone project worth of 3 credit hours. The courses are Management of Technology & Innovation, Operations Research for Engineers, Project Management for Engineers, Management Accounting and Financial Analysis, Decision Techniques and Data Analysis, Quality Engineering, Engineering Process Management, Supply Chain Management and Product Development and Marketing.

In the final capstone project course, case study method is employed to train the students to apply the subject matter learned in various courses in the program. Diagnosis ability, the production of knowledge by systematically analysing the available data, is aimed to be the outcome of this case study-based training carried out during the first half of the course. The students analyse a wide range of cases and

based on these, they learn how to generate various strategies. In the second half of the course, the students (in groups of four) engage in addressing a real-life or instructor-designed problem. This paper describes the case study method as delivered to a cohort of 34 students at United Arab Emirates University and the capstone project ‘Development of a Design Division for an Industry’ by one of the groups.

## **2 The Case Study Method – A Literature Survey**

A case study is defined as “*an empirical inquiry that investigates a contemporary phenomenon (the ‘case’) in depth and within its real-world context*”[3]. It is a method of research by which accumulated case histories are analysed with a view towards formulating general principles. The courses in the MEM program, unlike any other program, mainly focus on inputting knowledge because most of the courses and content are new to the students. The knowledge becomes wisdom, making the student competent, only when the knowledge is applied to solve some real world problem or outputting. In order to develop thought processes that enable outputting proposals for action in various areas of Engineering Management, the case study method provides training to analyse situations and environments. Querying the observations of the actual and available facts objectively, diagnosis is carried out to make decisions. As Golich et al [4] put it, a case is a story recounting, as objectively and meticulously as possible, real (or realistic) events or problems so that students experience the complexities, ambiguities, and uncertainties confronted by the original participants in the case. As the NASA document [5] states ‘A case study (or case story) may be understood best as a narrative, based on actual events, that creates an opportunity for conversation, problem analysis, and virtual decision-making. An effective case study transfers specific knowledge by placing the student or workshop participant in a position to think through choices faced by decision-makers in real-life situations. By confronting actual scenarios, participants develop and refine analytical skills for solving similar problems in their own projects’.

The main part of the case method training, is the ‘training to ask questions’. In describing the implementation of the case method, University of Albany [6] quotes from Rudyard Kipling’s poetry, which reads

*“I keep six honest serving men  
(They taught me all I knew);  
Their names are What and Why and When;  
And How and Where and Who”*

University of Albany has given a four-step methodology for the case study method, which is paraphrased as follows:

- a. *Preparing a Case for Class Discussion* - A case assignment requires conscientious preparation before class. One definitely cannot contribute or get much out of hearing the class discussing a case that he hasn’t read and prepared. Preparation includes studying the case, reflecting on the situations presented, and developing some reasoned thoughts. Preparation should end up with a sound, well-supported analysis of the situation and a sound, defensible set of recommendations about which managerial actions need to be taken.
- b. *Participating in Class Discussion of a Case* - A classroom environment, calls for one’s sizing-up of the situation, analysis, actions recommended, and why they are recommended. As the class discussion unfolds, fellow classmates may say some insightful things that were not thought of by everyone. Often

the comments of others in the class would expand one's own thinking about the case.

- c. *Preparing a Written Case Analysis* - The expectation is (a) identification of all the pertinent issues that management needs to address, (b) appropriate analyses and evaluations and (c) proposal of an action plan and recommendations addressing the issues.
- d. *Preparing an Oral Presentation* – Similar to a written case analysis, oral presentation requires identification of the strategic issues and problems, analysis of industry conditions and the company's situation, and the development of a thorough and well-thought-out action plan. As with a written assignment, it should demonstrate command of theoretical knowledge and tools of analysis. The recommendations should contain sufficient analytical evidence and details to provide clear direction for management. The main difference between an oral presentation and a written case is in the delivery format.

Addressing the question 'when the case study approach should be used?' Baxter and Jack [7] conclude that Case Study Method has the potential to deal with simple through complex situations and enables the researcher to answer "how" and "why" type questions. For the novice researcher a case study is an excellent opportunity to gain tremendous insight into a case. Similarly, Yin [3] states that a case study design should be considered when: (a) the focus of the study is to answer "how" and "why" questions; (b) one cannot manipulate the behavior of those involved in the study; (c) one wants to cover contextual conditions because they are considered relevant to the phenomenon under study; or (d) the boundaries are not clear between the phenomenon and the context. In short, the literature showed that the case study method provides training to ask questions and apply the knowledge gained in the taught courses, which in turn provides new knowledge to make decisions.

### **3 The Case Method as Taught in the Class**

The students in the class were divided into ten groups and each group had to take responsibility for one case study. Each week two groups gave an oral presentation for about 20 minutes each, and class discussions followed it. All students were given the case study one week before the presentation of that case study so that they could prepare for classroom discussion. The group responsible for the case study prepared the presentation and got ready to lead the classroom discussion. All students were requested to prepare a list of questions under the six headings what, why, when, how, where and who. On the day of the presentation, the groups responsible for that week's case studies were requested to give, in turn, a brief summary of the case first and then describe their questions, and the analyses they conducted to answer the questions. The discussion or evaluation of the questions and answers followed. Continuing this, additional questions from all students were listed and analysed. After the presentation and discussion, the group responsible for the case study summarised the entire proceedings and wrote the case report for circulation among the entire class. The process continued for all ten cases. For the midterm examination the students were given a case study/scenario one week in advance and they had to answer questions in the examination hall. The students were then given a project where they can apply what they had learned in the program, relevant to the project, with the benefits accrued from the case analysis practice they went through already.

A major benefit gained from the case study method is, ‘the questioning ability using the knowledge acquired through the courses in the program’, which they could use in their future projects. It was found that students, after the case study analyses, are comfortable in generating questions under the six headings, what, why, when, how, where and who, that would give better insights into the project they undertake.

#### **4 Development of a Design Division for an Industry – The Project**

In what follows, a description of the experience with the project, which is considered to be the subject matter of this paper, will be presented in more details. The first part of the project focussed on identifying the role of the “Design Division” in the industry. This was achieved through literature survey as well as through the questions raised in the manner learned in the case study method. The survey started with (a) identifying the functions of an engineering manager (b) the role of research and development division (c) the design process and (d) office organisation and resources. This was followed by systematically questioning the collected data, which in the end helped to establish a hypothetical model of a design division for the future. The hypothetical model was then trimmed to suit the requirements of the specific industry.

##### **4.1 Literature Survey**

This section summarises the literature survey carried out in the four aspects identified above, as relevant to the formation of a Design Division.

###### **4.1.1 Role of an Engineering Manager**

Chang [8] outlines, ‘leading from present to the future’ as one of the requirements of a modern engineering manager. He states that for the present the manager should (a) focus on keeping the company operating smoothly by ‘Doing the things right’ (b) pay attention to details (c) make sure that both financial and non-financial metrics are selected to monitor and evaluate company’s performance (d) contribute to continuously upgrade the current operations and (e) take care of tasks needed for the company to achieve profitability in the short term. For the future he asserts the need to seek (a) e-transformation opportunities to generate company profitability in the long term (b) opportunities to significantly improve distribution, price, service, features, and ordering services to enhance the value of company’s products to customers (c) development and introduction of new generation of products in a timely manner ensuring sustainable profitability and (d) development of a vision for the future, contributing to new company strategies related to technologies, and assisting company management in deciding what should be done.

###### **4.1.2 Role of Research and Development**

Research and Development, R&D, is a special function within a company focussed on the creation and improvement of products and processes, based on scientific research, and their application to the needs of the market. Companies that start with manufacturing and aspiring to migrate to designing and making their own products find the development of R&D activities as fundamental. Nu Angle [9] identifies seven elements within the architecture of R&D. The descriptions are paraphrased in the following way:

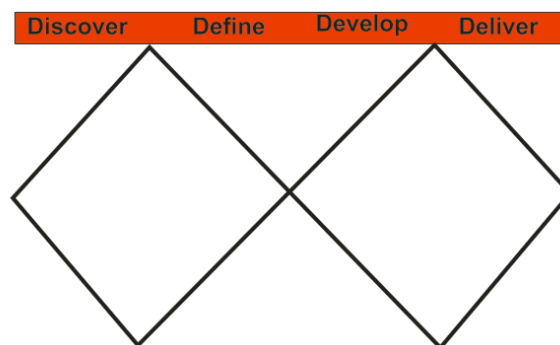
1. *R&D strategy* – helps the company to position its innovation efforts internally and externally by defining where to place emphasis and the direction for R&D.
2. *R&D process* – ensures that the right inputs and outputs are available to

support functions such as product development, research, technical service, marketing and manufacture. There is also a balance to be struck between process bureaucracy and responsiveness.

3. *Resources* – provide for developing the capabilities to encourage innovation; this includes tools, people, techniques and facilities.
4. *Organization* – ensures selecting the right structure for R&D allows processes and resources to work as efficiently as possible. Structures can be based on competencies, products, services or disciplines.
5. *R&D culture* – represents the values and behaviours that contribute to the unique social and psychological environment of an organization. Inevitably R&D redesign will require change and the most fruitful approach is to begin with leadership tools that include a vision or story of the future based on a sound R&D strategy. Change can be consolidated with management tools, such as role definitions, measurement and control systems.
6. *Information systems* – ensures that the right information is collected, sifted, analysed and communicated. R&D teams need to communicate in teams that are dispersed across the organization and may include partners, universities and technology consultants.
7. *R&D metrics* (or Key Performance Indicators) – KPIs are part of the Research & Development Dashboard or Balanced Scorecard.

#### 4.1.3 Design Process

In systematic approach to design, design model is the description of the stages or the sequence of activities the process goes through. There are several such design models. Design methods are tools and techniques that are being used at different stages in the design process. Looking at the various design models Wyn and Clarkson [10] state that ‘despite the extensive research undertaken since the 1950s, there is no single model, which is agreed to provide a satisfactory description of the design process’. The general consensus is that there is no set best practice in design process. However, there is agreement that there are some commonalities across processes used, and that these typically consist of four or five distinct phases. With these in the background companies choose a design stage model and add the required design methods at different stages to suit their needs to create their design model.



**Figure 1: Design Model by Design Council UK [11, 12]**

Design Council [11, 12] in 2005 has established the double diamond model developed through in-house research. It is a simple graphical way of describing the design process. Four distinct phases, Discover, Define, Develop and Deliver, maps the

divergent and convergent stages of the design process, showing the different modes of thinking that designers use. Each of the phases consists of a series of iterative loops and specific design methods, where exploration and testing of ideas can happen. It places emphasis on the Discover phase as one of the most critical, and the one that makes best use of the designer's knowledge and skills.

#### **4.1.4 Office Management**

The quality of the work environment is recognized to play a part in a candidate's decision to work for an employer. More importantly, in order to produce better service a systematic method should be employed to consider space and resource planning. Hassanain [13] identifies and classifies the factors that need to be considered in office space arrangement under three main groups including functional, technical, and financial factors. In addressing the question 'How are they, and how should they be organized to maximize the chances of a successful product development?' Sosa and Mihm [14] identify two fundamental challenges: decomposition and integration faced by companies. They assert that the overall design effort needs to be broken into individual tasks and more importantly the work carried out on these tasks needs to be integrated into an overall design once again. They identify functional, project and matrix organisation structures among others to carry out these functions. Meetings, and meeting room resources are some of the main requirements of a design office. Mulgan [15] identifies that providing written material, multimodal supports and multiplatform environments, support sense-making and common understanding in meetings. He asserts that minutes, images, networks, shared documents, and digitally shared information, all contribute to extend the process of information construction and exchange. He cites that boardrooms like the one at Procter and Gamble, which is surrounded by screens with data, and some others who use screens instead of paper. University of Cincinnati [16] applied the design of standard features such as area, furniture, technology etc for its faculty rooms and meeting rooms. Various sizes of meeting rooms with different facilities have been created by them to address different requirements.

#### **4.2 Questions, Answers and Evaluation**

Preceding survey provides a lot of information. This information was assimilated and converted into an actionable format or questions so that they can be incorporated when the design division is formulated. The fundamental question that had to be answered was '*What are the functions of the design office and how the design office can be formed to best-deliver these functions?*' Some of these functions are common to all design divisions, while some are specific to the company trying to use this method to design their design division.

The method adopted by the group had two stages. In the first stage they carried out the literature survey as described above. In the second stage they used the questioning technique learned in the case method to ask questions treating the literature surveyed, as case descriptions. Table 1 enumerates the questions that were established from the four areas surveyed. The group then discussed answers to these questions, which in turn helped them to formulate the strategy for a design division.

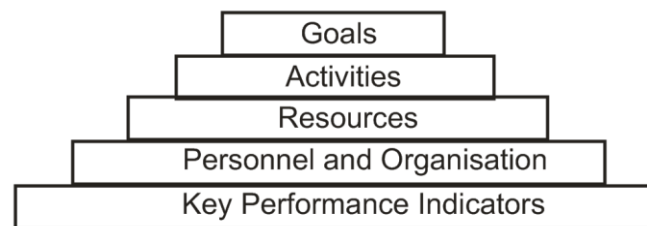
**Table 1: Questions Raised Based on the Literature Review**

<b>Questions triggered by Engineering Management and R&amp;D</b>	<b>Questions Triggered by Design Process and Office Management</b>
<ol style="list-style-type: none"> <li>1. How to ensure smooth operation of the company?</li> <li>2. Why the company should upgrade its current operation?</li> <li>3. How to take care of tasks needed?</li> <li>4. What details the design office should consider?</li> <li>5. How design office can help to keep attention to details?</li> <li>6. How to develop new generation of products and services?</li> <li>7. How developing visions for the future be integrated?</li> <li>8. What are the e-opportunities available?</li> <li>9. What platforms are adopted by the sector of the company?</li> <li>10. What are the capabilities needed to embrace e-opportunities?</li> <li>11. How e-transformation will improve current condition?</li> <li>12. How the new technologies will be required?</li> <li>13. What are the steps needed to ensure short-term profitability?</li> <li>14. What is the strategy for the R&amp;D activities?</li> <li>15. What outputs and outcomes are expected from R&amp;D?</li> <li>16. What inputs are needed for the listed outcomes above?</li> <li>17. What are the tools needed to assist R&amp;D activities?</li> <li>18. What facilities, people and technology are needed for R&amp;D?</li> <li>19. How the company can encourage innovation activities?</li> <li>20. How R&amp;D should be structured and organized?</li> <li>21. How to provide a facelift to the current design efforts?</li> <li>22. What outcomes are seen as achievements of R&amp;D?</li> </ol>	<ol style="list-style-type: none"> <li>23. How the right information on past and future designs and processes can be made available for immediate accesses?</li> <li>24. What is the design process to be adopted?</li> <li>25. What phase of the design process is the main concern?</li> <li>26. What are the tools, software etc are needed in the identified phase?</li> <li>27. What are the tools to discover the problem (potential) area?</li> <li>28. What facilities have to be provided to enhance creativity?</li> <li>29. How to ensure availability of the good practices established methods and the lessons learned?</li> <li>30. How the design project is divided into tasks for individuals?</li> <li>31. Who allocates the integration and division tasks in design?</li> <li>32. How the solutions of the divided tasks are integrated to form the solution?</li> <li>33. What is the best arrangement of the working office station?</li> <li>34. What are the main requirements of a design office?</li> <li>35. What are the roles the meeting rooms have to play in the Design Division?</li> <li>36. How the space, technology etc are provided?</li> <li>37. What are the design challenges facing the company?</li> <li>38. What are the main items that have to be preserved?</li> <li>39. Who is responsible for the overall activities in Design Division?</li> <li>40. Who are the designated persons or office bearers in the design division?</li> <li>41. What is the organization chart?</li> </ol>



### 4.3 Hypothetical Model of a Design Division

A hypothetical model for a design division was developed based on the literature survey and the insight formed from the diagnosis through the questioning technique. The hypothetical model starts with the identification of the goals of the design division as its top layer. Several questions in Table 1 can be grouped under this category. In the next layer the activities that have to be performed to achieve the goals are established. This again is based on the questions in Table 1. In the next layer the resources that are necessary to perform the above activities are specified. The next layer defines the personnel and their organisation to best carry out the activities and achieve the goals. Finally the key performance indicators necessary to monitor and control are defined. Figure 2 illustrates the hypothetical model.



**Figure 2: Hypothetical Model of a Design Division**

The goals are derived mainly from the ‘why’ questions. The activities are the result of the ‘what’ has to be done to achieve the goals. The resources are the answers to the ‘how’ questions and the personnel and organisation are based on answers to the ‘who’ question. The key performance indicators are measures of the appropriateness and effectiveness at each level.

## 5 Design Division for a Local Company

The methodology was developed and applied to develop a design division for a high tech manufacturing company, which manufactures composite components for leading international companies. The international companies use them in their leading products. It was started in 2009 with secured orders from these companies and started production in 2010. Having overcome the initial entry and learning problems the company has established itself as a reliable manufacturing partner for these international companies. They have gained clear knowledge and experience in manufacturing and the implications of manufacturing in the production of high quality end products. They have understood the implications of manufacturing defects that can have compromising effects in the design. Being in the manufacture of components in the cutting-edge of the high-tech sector they learned the importance of the stringent standards for testing and passing or approving components for use. The nature of the industry of their international customers dictates changing (to more stringent) standards in short notice.

### 5.1 The Goals

The influential relevance of design on the manufacturing and resulting quality made them to realize the need for a design division that can (a) act as a reliable and efficient repository for designs with associated experiences (b) use very fine analytical

software and verification facilities so that the effects of manufacturing defects can be reliably estimated (c) established good practices and examples that can be used in future activities (d) a design model to suit their needs, and (e) a structured division with designated positions to carry out the functions and develop the capability to receive technology transfer from experts as and when appropriate. These formed the goals.

## 5.2 Activities

The activities of the proposed design division can be summarised in the following way:

***Problem identification*** – At this stage the problem has to be clearly understood and defined and this involves the knowledge of composites, structural design and application related theories. In depth analysis may use a defect concentration diagram as the starting point and an in-depth survey of literature and standards, execution of specific projects and discussion with the customers. Several meetings and discussions may be part of this process. In the end a definite problem statement and defined success criteria are established.

***Analysis of the problem*** – Analysis starts with establishing the current knowledge in terms of published data and established good practices of both internal and external categories. The established data is then analysed to establish the purpose of the design and the design rules to be applied. Here again meetings and discussions form an important part of the activities.

***Design process*** – The design process is kicked off with an Engineering Change Request and Engineering Change Order, and closed with a Change Order Closure in accordance with the change management system. A stage gate management is employed to manage the process from stage to stage with defined outputs from each stage. A design stage model with associated design methods has been defined for this purpose. This is one of the areas where a lot of engineering effort is made individually and integrated.

***Verification and validation*** – The design is subjected to various analyses using advanced computer-based tools to verify and validate the designs. This is a specialist activity and requires a lot of resources in terms of e-facilities and skilled personnel. Analyses required for validation takes a lot of time and new technologies are introduced in the market on a frequent pattern. Thus acquiring the new techniques and technologies is a constant additional requirement for this section. The verification part should ensure that the new design meets the specification in full.

***Implementation*** – Design Assurance, DA, is an independent assessment to capture any omissions at the design stage before its committal to manufacture. It is a tool to check the adequacy and efficacy of the design. DA ensures that the end product meets or exceeds customer expectations. DA works with the team and being a team of experts provides expert insights and additional support to achieve the end goal.

## 5.3 Resources

The resource requirements for this design division are mainly in the electronic or software format. They can be classified under the following categories:

***Approved and common tools*** – This includes software packages like the Microsoft office, list managers, capture tools, brainstorming tools, adobe, and many others.

***Robust Design Guides:*** Being in the cutting edge of the high-tech sector the design process and the proving of the designs are governed by design guides. These guides are often updated and a tracking of them and making them available and accessible is

a fundamental task. This is one of the main requirements. Another important item is the proven design manual which outlines the set-menu procedures for standard problems within the sector.

***Robust configuration and data management system*** – The importance of this needs no mentioning. The system should provide access to the design guides, design manual and standards at the press of a button. It should manage the data generated at all phases of the design in an orderly fashion so that all data generated can be made available for use at a later stage.

***DA requirements*** – Information about assessment to verify and validate various requirements and stipulations specific to the sector. This may include standards, test procedures and the like.

***Demonstrated technology readiness and manufacturing readiness*** – These are essentially case studies of various kinds that can give insights and understanding of complex procedures. This should also provide facility for viewing these case studies and self-brainstorming or dreaming.

***Hardware support for effective Meetings*** – The entire set of activities in the design division outlined above needs several meetings both with internal personnel and external experts. The meeting rooms should be equipped with multi-screen facilities and strong hardware and software support to facilitate meaningful discussions. There should be many meeting rooms with different capacities.

#### **5.4 Personnel and Organisation**

This section only highlights the importance of these two aspects. The fundamental and most valuable resource for a design division is the competence of the personnel. The division should have a leader who knows the way, walks the way and leads the way. The division should have a team of motivated engineers with different knowledge, skills and talents. The division should have capable intermediate managers who can lead their teams towards the goals. They should have authority in par with their responsibilities. A clearly defined organisation structure is fundamental to the design division. Another fundamental requirement for a young company is the provision of regular training and knowledge building programs. Being in the high-tech sector this should include training by international experts.

Another important aspect is the space management in the design office. The first and foremost is the allocation of space for several well-equipped meeting rooms of different sizes. These facilitate meetings and discussions of high quality. The next important item is the working station for individual engineers. The importance of the facilities and space cannot be over emphasized.

#### **5.5 Key Performance Indicators**

KPIs tells the management how effective and efficient the design division is. There are several KPIs suggested by various quarters to measure the effectiveness of engineering design. However the KPIs should be developed to meet the objectives of the company, which forms the Design Division. The work on this project suggested the following KPIs.

***First time quality of the design*** – This evaluates whether the design team has fully comprehended the design problem, developed the solution, carried out necessary and sufficient analyses and carried out the required verification and validation checks so that the Design Assurance passes the design with minimal additional requirements in the first time. This is a measure of the competence of the division.

***Client Satisfaction Ratings*** – The improved design at the end has to be approved by the client. Hence the client satisfaction rating is a clear indication of the effectiveness or quality of the design.

***Development of repeatable procedures*** – Design processes in the high-tech sector is very special and companies develop in-house good practices or methods. Number of re-usable procedures and techniques developed within the design division is a good indicator of the quality of the division.

***Activity follow-up*** – Each project will have activities such as meetings and evaluations. A record and analysis of these could give an indication on the active nature of the project.

***Comparison between budgeted or estimated time and actual time*** – Finishing the task with reliable and satisfactory results in the budgeted time is a clear demonstration of competence.

Details beyond this point require commercially sensitive data with respect to the actual structure, resources and activities of the division and therefore have been avoided from public domain.

## **6.0 Analysis and Student Feedback**

The Capstone project course has the following learning outcomes:

- 1 Apply knowledge and skills gained in other MEM courses
- 2 Analyze and illustrate case studies systematically
- 3 Analyze and evaluate engineering scenarios
- 4 Evaluate and propose improved solutions to existing divisions or companies
- 5 Design an administrative system for engineering divisions or companies

Four assessment tools were used to assess student performance. In the first tool, the presentation of the individual group's case study was assessed while in the second tool, their report was assessed. Each one of these assessments carried 10% of the final marks. Sizing up the problem, identifying the relevant theoretical component, and getting full insight by asking questions and the ability in oral and written communication were the criteria used. In the third tool, the midterm examination, the students were given a 53-page scenario report on technology management, originally presented in a UNIDO workshop. It was given one week ahead of the examination so that they could study and explore. The document contained a lot of useful approaches and techniques that the students can use in their future career-related tasks. The students were tested on their ability to size-up and use these techniques together with their subject knowledge. The final tool was a group project, where the students were asked to develop a part or whole of a business or introduce a new tool to an existing industrial set-up. The instructor providing the course assessed the case presentations and the mid-term examination while a panel of judges assessed the project presentation. The first author of the paper is the instructor, the second author is a member of the panel and the third author is a student who participated in the project.

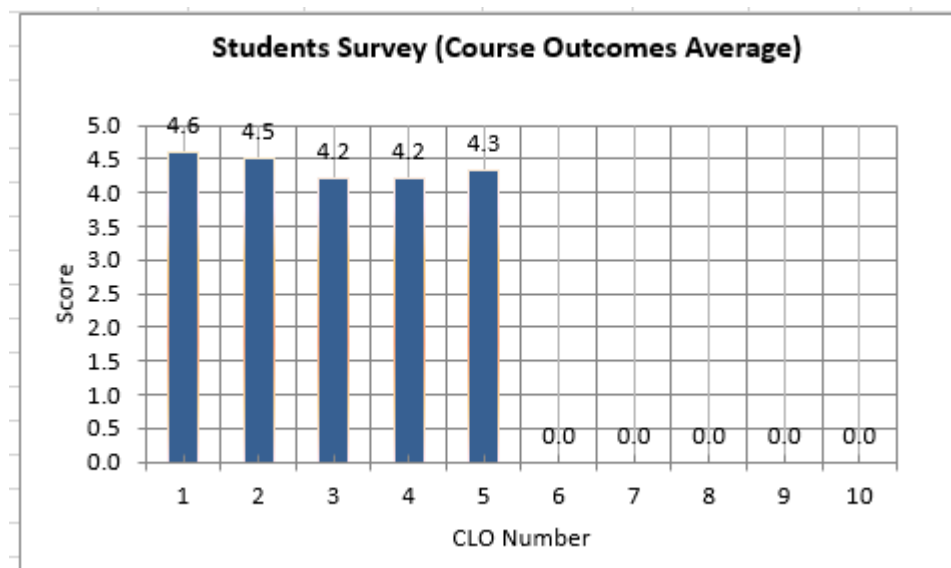
The results achieved by the 34 students are shown in Table 2.

**Table 2: Grades Achieved by Students**

Grade	Number of students	Percentage
A	20	58.82
A-	11	32.35
B+	2	5.88
B	1	2.94
Below B	0	0
	34	100

From the point of view of the course instructor the results show that the students have learned how to use case studies to understand the methods of application of the theoretical knowledge acquired. The project is such an application.

The students at the end of the course were asked to evaluate the level of achievement in each of the five learning outcomes on a 1 to 5 scale. This is a routine practice at United Arab Emirates University. Twenty-seven feedbacks that came from the students were analysed and the course outcome averages are shown in Figure 3 below.



**Figure 3: Student Survey**

As can be seen from Figure 3 the first outcome 'ability to apply knowledge and skills gained in other MEM courses' scored the highest. This was one of the concerns the students had in the past. The case study method has alleviated it. The next highest was the ability to systematically analyse case studies. This again indicates the liking of the method as a useful one. Analysis of scenarios and existing setups scored a healthy 4.2, but were the least in the cohort. Designing the administrative system scored 4.3 as students started realizing the relevance from the case studies and projects.

The real value however is dependent on the choice of case studies and projects. In this context it is worth mentioning that availability of engineering case studies are limited

compared to business case studies. The instructor has given the achievement rating of the outcomes as {4.5, 4.2, 3.8, 4, 4}. This may be a reflection of the relevance of good case studies.

## **7.0 Discussion and Conclusion**

The Foundation for Critical Thinking [17] defines critical thinking as, '*the intellectually disciplined process of actively and skilfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action*'. Industry expects the graduates to have in-depth theoretical knowledge and critical thinking ability. The case study method is an effective tool for training in critical thinking. It demands thought provoking questions and their answers, originating from subject knowledge. The answers to the questions provide opportunities to think from different perspectives and permit the formulation of different strategies to conduct the event. The first part of the paper explores the case study method and its pedagogy. The second part of the paper investigates the design division, the stage to perform design activity. It collects the details of the constituents of a design division and systematically analyses them and regroup the data to form the hypothetical model of a design office. The section on design division for a local industry describes how a high-tech composite product manufacturing company can use the hypothetical model to organise a design division. Since its design needs to revolve around the designs they already manufacture for clients, their efforts are focussed on defect mitigation. This involves the detailed design or analysis. The goals, activities, resources, personnel and organisation and key performance indicators are established for the design division. Finally the students' performance and feedback were analysed.

From the experience gained it is safe to conclude the following:

1. Case study method is appropriate to train students in diagnosis, which is the production of knowledge by systematically analysing the available data.
2. The diagnosis process is facilitated by subject matter learned in different courses taught in the engineering management program. This shows the way to apply the knowledge in an integrated fashion to solve real-world problems.
3. Ability to ask structured questions is fundamental to the case study method and to integrate the knowledge towards finding a solution to an existing or new problem. In establishing the questions about the design division the students have demonstrated this.
4. Depending on the activities undertaken by the company, the stage of operation of the company in the design council's design model would vary. Some may operate in the Discover stage while some may in the Develop stage, which requires a lot of analysis. The company for which the design division was developed operates in this area. This requires lots of analysis and evaluation and the design division should be designed to support it.
5. The work in this project established a hypothetical model for a design division, which has to be adapted to suit individual company's requirements.

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