Engagement of Safety Management Into 3D Model Design and Construction Plan in Petrochemical Industry

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Abstract

Many employees in 3D design stage and construction planning have insufficient awareness of safety knowledge. During the implementation of a project, most of the three areas are carried out independently. Therefore, construction stage time is wasted and potentially increased risks. At the same time, construction plan will be affected in the progress measurement and monitoring management. Technically, quantitative physical measurements and qualitative occupants' perceptions of safety knowledge are limited due to practical challenges and research gaps. How to verify the applicability of the combination of 3D models and safety knowledge became focus in this paper. This paper conducts quantitative analysis and questionnaires to collect data from 124 employees in related fields of petrochemical industry construction. While addressing a number of research gaps, this research provides a holistic approach which acknowledge the engagement of safety knowledge in certain area. This paper contributes to fill an important information with findings that employees show a preference for increasing safety environment in construction site with safety knowledge embed with 3D model design.

Key words: Safety management,3D model design, Petrochemical industry

1. Introduction

The causes of industrial disasters in the petrochemical industry are usually divided into two types, human and equipment factors[1]. The general chemical disasters include human factors, equipment factors and environmental factors. The chemical disasters caused by operational failures during the manufacturing process included: (i) unfamiliarity with chemical reactions that occur during the manufacturing process, (ii) improper engineering design; (iii) improper control systems, (iv) operating procedures and Improper training[2].Human errors are mainly caused by insufficient design(22%) or lack of procedures(17%)[3]. The lack of procedures not only means that there are no programs for specific tasks. Other reasons included in the concept of human factors and organizational factors, those are lack of training or insufficient training (11%), management of the organization (9%), inappropriate maintenance (4%) and inspection

(3%), and operator errors (11 %)[4]. The accident resulted from unskilled workers, ignorance of safety regulations, unpredictable working environment, and most importantly, the lack of advanced safety control technology, and tools that can identify dangerous behaviors and unstable structural elements[5].. Construction design information will be passed on to the construction personnel to provide the user with a final design intent from all angles required for construction work[6].

The design information was used for construction planning and job execution, and could be used for safety planning and hazard identification tasks. Emerging technologies, including databases, computer-aided simulation, and visualization, provide new opportunities to enhance safety programs. Construction site design needs to be carried out at different stages of the construction process[7]. Generally, the safety information was used on site does not reflect the factors involved in the actual construction work environment, which makes it more difficult to identify potential safety risks and provide the right staff with the right information at the right time during construction [8].Traditional 2D engineering drawings and paper-based safety planning sources limit the ability to identify and analyze hazards before construction . Pervious researchers believe that CAD does not provide an effective platform to obtain spatial information, and 2D information leads to inefficient information retrieval. The information retrieval tasks require users to manipulate multiple drawings to understand the site space. Therefore, it is speculated that these limitations will lead to poor safety plans, process productivity, and awareness among workers[9].Safety operation is one of the key factors in meeting the growing market challenges of the chemical and petrochemical industries[10].

In order to achieve safer plant operations, process safety must be ensured during the process design stage. Safety design methods are widely used to evaluate safety during the design phase so that the harmful effects of potentially dangerous events can be avoided or mitigated during the design phase. Connecting safety management tasks to the 3D model provides new opportunities for checking and evaluating safety during construction[11]. This study proposes a new system framework that combines PDMS model technology with operational safety analysis and applies it to pipeline replacement operations. It has a strategic role in the entire design process to meet safety objectives, project time, and cost requirements. Therefore, this study was conducted with purpose to verify the applicability of the combination between 3D model and safety knowledge.

2. Literature review

2.1 Implement 3D Model in Petrochemical

The project design of the petrochemical industry involves many disciplines, and the workload is also very high. The use of 2D design software directly affects the design quality and work efficiency[12].However, the 2D system inefficiency of work, and

many procedure involve human operations, such as material check, welding quantity, pipe diameter length[13].Plant Design Management System (PDMS) is 3D plant design software effectively solving the above problems, including; creating pipeline catalogs and specifications; establishing design models of various disciplines; verifying all designs and generating engineering drawings. PDMS systems automatically check collision potentials to ensure the accuracy of design and effectively avoid impact that may cause system failure in piping design[14].PDMS is generally a design software composed of modules such as project creation, engineering database, equipment, piping, steel structure, electrical and instrument cable bridges, etc. It has powerful modeling functions and excellent drawing functions[15]. At present, many chemical projects use three-dimensional piping software (PDS, PDMS) for construction drawing design and 70% of the time in the project is used to create, check, and modify the model.)

2.2 Job Safety Analysis in Petrochemical Industry

In Job Safety Analysis (JSA), a complete operation process needs to be divided into individually determined steps, hazard, and consequence analysis in gradually operation step[16].The implementation of JSA method to conduct hazard identification, risk assessment, and formulate risk control variables to each phased operation activity. This is an important step to maintain pipelines in petrochemical plants[17].Consist of practical method for identifying, assessing and controlling industrial process risks. The main benefit of JSA is a simple tool to helps highlight the dangers of risky operations. Both managers and employees be able to understand the hazards for specific tasks by executing JSA[18].Another benefit of JSA is easy method to used and directly related to workable tasks. In order to better understanding in work safety, need to engage employees and JSA in the preparation of analysis[19].

2.3 Engagement of 3D Model Construction and Safety Management

The building Information Modeling-based automated tool development that can help detect potential fall hazards, included the risk of falling from the slab leading edge, slab hole and opening[20].Traditional security planning methods are mainly aimed at static information, implicit knowledge, regulations, company security policies and 2D drawings[21]. As a result, there is currently no specific solution to site-specific dynamic information, time, and space information. Existing research report has a connection between the design development and the construction site condition[22]. Engagement safety management tasks to the 3D model design providing a new opportunity for checking and evaluating safety during construction[23]. For instance, it can strengthen cooperation in safety planning and another way to enhance over safety insightful.

3. METHDOLOGY

3.1 Research frameworks

Petrochemical construction is a high-risk operation project in Taiwan. Therefore, it

is necessary to consider the risk of on-site operations from the initial design stage. The safety management system can provide a source of information on the potential hazard in field operations, Therefore, importing the potential risk information into the 3D model design is the main framework of this research.

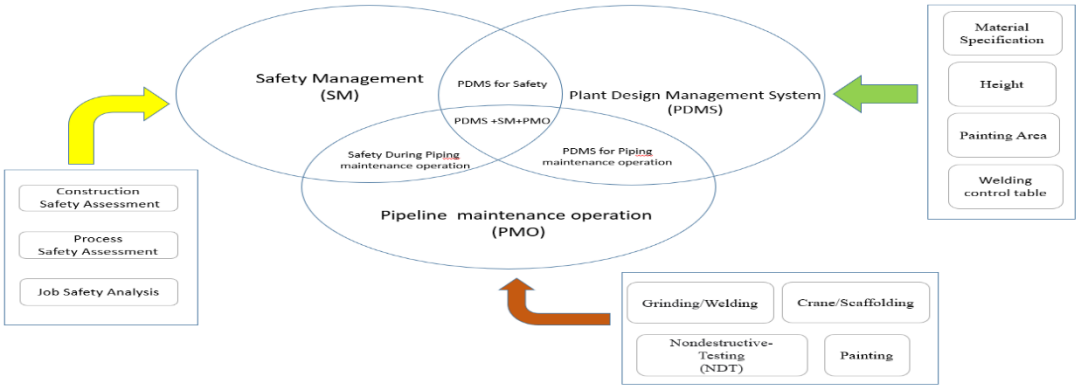

Figure 1. Research Framework

3.2 Population and Sample

This research took the relevant employees of petrochemical plants (including project managers, pipeline design engineers, safety management personnel and pipeline construction personnel) as the research samples. From this sample were collected data whether they have different views and suggestions on safety management analysis and evaluation into the pipeline 3D design stage.

3.3 Data collection

The formal questionnaire data collection method of this research adopts a convenient sampling method. The online questionnaire was notified by e-mail and sent to the entity to fill it out in paper and written form. In order to ensure the effectiveness of the formal questionnaire collection, the subjects of the formal questionnaire will be sampling by position, age group, and working experience. This research questionnaires were based on the scale developed by related research institutes in the past, and the petrochemical manufacturing practitioners in the Yunlin area will answer the question according to the degree of agreement to the measurement question:(1)The first part is basic personal information (covering position, age, and years of employment); (2) There are 25 questions in the second part, and using five-point Likert scale.

3.4 Data Analysis

The SPSS 22 and statistical package software was used to perform statistical data analysis, included: descriptive statistical analysis, reliability/validity test, correlation analysis, regression analysis. This method approach was used to lead in research purpose in this study.

4. Result

During the survey period of 2 months, a total of 200 questionnaires were deliver and 166 were returned; after deducting incomplete and random questionnaires, a total of 42

questionnaires were obtained. A total of 124 valid questionnaires were obtained, and the effective questionnaire rate reached 74.69%.

4.1 Descriptive Statistical Analysis

The table-1 describes the breakdown of the descriptive information of the survey respondents by genders, age groups, jobs class, work experiences, and type of professional fields. The data was collected from the population of all petrochemical industry related fields. In the high-risk petrochemical industry, men still account for most of the proportion; the older part was mostly middle-aged; the position class was mostly engineers; the proportion was mostly 6-10 years of work experience, and the professional field is mostly on-site supervision.

Table 1 Descriptive statistic

Classification		Sample	in %
Gender	Male	98	79
	Female	26	21
Age	30 years old (including below)	24	19.4
	31~40 years old	73	58.9
	41~50 years old	22	17.7
	51~60 years old	5	4
Position	Manager	20	16.1
	Engineer	78	62.9
	Basic level person	26	21
Work Experience	5 years (included less than)	43	34.7
	6~10 years	52	41.9
	11~20 years	18	14.5
	21~30 years	10	8.1
	30 years or more	1	0.8
Fields	Design modeling	34	27.4
	Construction planning	57	46
	Operation safety	33	26.6

4.2Reliability/validity analysis

In order to ensure the validity and reliability of reasonable subsequent data analysis, this study uses Cronbach's alpha (α) to check the internal consistency of the structure. According to reliability test, Cronbach's alpha (α) was greater than .7, indicating that the measurement of the index had good reliability. In the following table, α represents the reliability of the measurement structure: Design modeling was got .794, Construction planning.813, Operation safety.812, and Safety knowledge.807. These scores meet the general requirements of the field, indicating that the reliability factor is higher than 0.7. Therefore, we believe that this study has good reliability. According to the validity test result of Pearson Correlation scores are from.212 to.769 (N=124), which is has meant more higher than the r-table required standard of.176 (N=125).

Table 2 Reliability test

Variables	Cronbach's Alpha	N-Item
Design modeling	.794	6
Construction planning	.813	7
Operation safety	.812	7
Safety knowledge	.807	5
Total	.932	25

4.3 Correlation Analysis

From the results in the table below, it can be interpreted that the four variables are positively correlated, and they are moderate. In particular, the design modeling and construction planning are the highest, so it can be explained that the promotion of a project requires consideration of the construction site planning and the predicament that it will face in the future during the 3D model construction period. The second is the impact between Construction planning and Operation safety. Therefore, it can be understood that for different engineering characteristics, it is necessary to strengthen labor safety and health equipment, improve the working environment and implement inspections. The purpose identifying correlation variables is to effectively reduce the incidence of occupational disasters, ensure labor safety and health, and ensure management Effective operation of the system. Although the variables of Design modeling and Safety knowledge are the lowest, the results show that they are still moderately related. It can be inferred that model construction engineers spend most of their time indoors and do not have much contact with the field of safety management. Awareness of safety knowledge will be considered in the future issues.

Table 3 Correlation analysis

Construct	Design modeling	Construction planning	Operation safety	Safety knowledge
Design modeling	1			
Construction planning	.755**	1		
Operation safety	.669**	.714**	1	
Safety knowledge	.668**	.678**	.673**	1

From the table-3, shown that result of correlation analysis had significant in every variable to another variables. Focus on major topic regarding safety knowledge had correlation to another variables, and the answers were significant .668 to design modeling, significant .678 to construction planning, and significant .673 to operation safety. It is meant that equip safety knowledge in 3D model design had correlation with next step in petrochemical industry, that is 3D design modeling, construction planning, and operation safety.

4.4Regression analysis

A research model of the relationship between variables and variables mainly explores the linear relationship between the independent variable and the dependent variable. Through the establishment of regression models, the influence of the variables between each other can be inferred and predicted. Independent variable is safety knowledge, then dependent variable is design modeling and construction planning.

Table 4 Regression analysis

	Design modeling			Construction planning		
	R Square	F	Sig.	R Square	F	Sig.
Safety knowledge	.446	98.232	.000[b]	.460	103.972	.000[b]
Construction planning	.570	161.645	.000[b]			

Table-4 shown that regression analysis R square among safety knowledge, design modeling, and construction planning had significant result with sequence scores were .446 to design modeling, and .460 to construction planning. The meaning of significant is safety knowledge give positive effect to another two variables else. The explanation from table-4 that the R Square of Construction planning and Design modeling is higher, which is means that Design modeling will positively affect Construction planning. Then there is the relationship between Safety knowledge and Design modeling. Between the two, we can understand that Safety knowledge will positively affect to Design modeling. Therefore, we be able to evaluate that the value of safety knowledge is inseparable from the design of the initial model or entering the construction planning stage.

5.Discussion

5.1 The 3D Models Design Need to Equipped with Safety Knowledge in The Petrochemical Industry

The factors affecting occupational hazards in the petrochemical industry are a combination of multiple factors[24]. Among them, the status of disasters that occur in the workplace is roughly similar, and similar occupational disaster situations or conditions or conditions have also occurred repeatedly. Automatic Rule Checking is an important technology in the application of 3D model[25, 26]. In recent years, many studies have applied automatic rule checking technology to the safety and health management of engineering projects. Through the semantic analysis and logical translation of major risk events, the 3D model in the construction planning stage can identify locations, areas or spaces where risks may occur[27-29]. We can make corresponding measures and plans in advance to eliminate risks intangible before disasters occur. Among them, drawing a plan of the safety signs is the key to implementation. In the actual operation process, when drawing the safety sign plan, it is necessary to set up the plan according to the safety sign[30]. The use of two-dimensional drawings to express complicated safety sign information is likely to

cause a disconnect between the information[31]. Therefore, traditional construction safety sign management has disadvantages such as poor communication of safety sign information and difficulty in self-inspection.

Traditional hazardous workplace assessments mostly use written descriptions for the management of safety knowledge, and the use of safety knowledge and information is still insufficient. Based on the relevant information provided by the 3D model, it is possible to systematically and automatically analyze the situation that the petrochemical industry needs to install safety protection measures during the construction phase, so as to provide on-site operators, safety management personnel, and safety supervisors in real time and the correct safety protection information be able effectively to improve the effectiveness of operation safety management.

5.2 Safety-Knowledge Have Potential to Increase Safety in Construction Plan

The safety management in construction site of the petrochemical industry is a very important issue. The reasonable and correct use of safety signs at the construction site can improve the preventive ability of construction personnel and reduce or avoid the occurrence of safety accidents.[32].The traditional implementation process of construction site safety signs management is; (1) identification of construction safety hazards; (2) identification of dangerous operations, dangerous points, and dangerous areas; (3) safety signs setting; (4) safety signs plan drawing ; (5) Hanging of safety signs; (6) Safety disclosure; (7) Inspection and maintenance of safety signs.[33].In the planning stage, safety must be regarded as an important part of construction activities. The definition of safety and health requirements should be the same as the construction activities in the work breakdown structure. Then, these safety-related activities must be included in the project schedule. The result is a proactive safety plan that incorporates safety into the project as early as possible before harm is caused. When viewing the project schedule, the project team can understand the safety requirements and their own tasks[34]. The necessary resources required for safety performance can also be appropriately allocated and purchased in advance. The research explored planning tools that integrate health and safety into buildings. Tried some tools, such as safety information on drawings, responsibility maps, to reduce a lot of bureaucratic paperwork.

5.3 Considering Safety-Space In 3D Model Design Bring Positive Effect into Construction Plan

The management safety of construction with 3D model technology is mainly to take into consideration the technology and construction methods of construction safety in the design and planning stage. For example, for special-shaped buildings, it is assumed that construction such as construction is not easy to set up. At this time, 3D models can be used first design the construction frame, conduct construction feasibility

assessment at the source, and do a good job in project risk management and control. The shape of the building is particularly complex, which can eliminate problems before construction, which is conducive to work progress and safe promotion. With the aid of 3D models, it is easier for construction manufacturers to review the conflicts of various construction interfaces in advance. For example, in the process of project execution, people of different types of work and different fields can use the 3D model for integrated simulation based on the built 3D model. When the project is implemented, the 3D model can be used to communicate and discuss in the implementation. The control of the construction method and the entry time of the types of work, and the control of the manpower scheduling. It is worth mentioning that the 3D model can implement quantitative estimates in terms of safety and health hypothetical projects, especially for the installation of necessary safety and health facilities, and can confirm the integrity of the configuration of safety facilities.

6.Conclusions

From the results and discussion, we know that most site engineers and managers were agree that the combination of safety knowledge and model design at the beginning of the project will help a lot in the future stage planning. In the design engineer side view, how to improve the awareness of safety knowledge will it is an important subject in the future. It should not only focus on one's own work field. We believe that the combination of the two fields in the future will be a crucial help for the future construction and maintenance of the petrochemical industry.

Acknowledgment

The 3D model design in this study just focus on petrochemical work field, and in Taiwan company setting. In addition, company in Taiwan in become place to conduct and collect data is one of biggest company in petrochemical.

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