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Assessment model for equipment risk management: Petrochemical industry cases

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ABSTRACT

This study presents an assessment model that examines quantity and quality factors for equipment risk management in the petrochemical industry. The proposed model has five dimensions—financial performance, logistical support, service level, learning and innovation, and risk control. This evaluation model uses 13 strategy subjects and 78 performance-measurement indicators. Performance assessment indicators are initially established and revised based on expert opinions collected via a questionnaire. Further, the analytical network process (ANP) is utilized to calculate the weights of indicators in each layer and to construct assessment models with applicable and valuable references. To determine model practicability, this study assesses four subsidiaries of the case company. Each subsidiary has a capitalization exceeding TWD 50 billion. In addition to evaluating company performance in terms of each dimension and indicator, the proposed model provides a valuable reference for decision-making in equipment risk management.

1. Introduction

As a producer of petroleum and natural gas, the petrochemical industry produces over 95% of the global output of organic chemicals and derivatives such as plastics, detergents and chemical fertilizers. Statistics from Taiwan's Board of Trade show that the output value of the domestic petroleum industry exceeds TWD 3 trillion, *i.e.*, more than 30% of overall value for manufacturing output. Petroleum continues to profoundly impact Taiwan's economic development.

Although the petrochemical industry worldwide has grown rapidly over the last five decades, major accidents still occur frequently, resulting in considerable losses. For example, a leakage of toxic gas at a Union Carbide facility caused over 2000 deaths in Bhopal, India, and an explosion in the LPG plant in Mexico caused over 500 deaths. According to a 1998 investigation by the American Petroleum Institute, of 100 major incidents in the last 30 years, 44% were caused by machinery failure and 12% by unknown causes. Thus, proper equipment risk control is essential to preventing major incidents.

Preventive and provisional maintenance have been transformed into risk- and asset-oriented reliability maintenance in the evolution of equipment risk management. Notably, current industrial practices have certain defects, which provide material for research into subjects such as inadequate cognition levels, lack of professional knowledge, absence of evaluation tools, and disarticulation of horizontal department integration.

While focusing on equipment risk management, the anatomization of difference, and potential defects in the petroleum industry, this work integrates a three-stage procedure, two-stage questionnaire and advice from industry and academic experts to construct relevant strategic subjects and performance evaluation indicators. The proposed evaluation model comprises five major dimensions—financial performance, logistical support, service level, learning and innovation, and risk control. For performance evaluation, academic and practical implementations by businesses have generally been based on group opinions, expert opinions, management decision models, and mathematical programming (Forker, 1997; Chen et al., 2004; Yang et al., 2009; Promentilla et al., 2008; Sucky, 2007). Based on the relative importance weights calculated using the analytical network process (ANP) (Saaty, 2005), this study develops a novel system for assessing equipment risk.

To verify the effectiveness of the assessment system, actual operations at four subsidiary companies are evaluated. Evaluation results indicate that firms can reduce equipment failure rates, decrease maintenance expenses, detect failure risk, improve diagnostic techniques, improve maintenance quality and reinforce the synergy of enterprise maintenance resources.

2. Assessment of equipment risk management

While assessing equipment risk-management performance, previous studies measured equipment maintenance. Pintelon and

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Van Wassenhove (1990) proposed several dimensions, including budget, equipment, personnel, materials and work, and compiled 20 performance indicators. Dağdeviren et al. (2008) proposed an early warning model to predict faculty behavior risk in a work system. In this early warning model, three main factors—organizational, personal and job-related factors—and 13 sub-factors were adopted. Tuzkaya and Önüt (2008) constructed a transportation-mode selection system. Eight criteria clusters—product characteristics, flexibility, reliability, speed traceability, costs, safety problems and risks—and 32 sub-criteria were determined to select the best transportation mode. This study summarizes literature focused on the four dimensions of work planning and scheduling, equipment maintenance expenses, labor hours and equipment efficiency, and extends 24 performance indicators (De Groote, 1995; Westerkamp, 1998; Mathew and Kennedy, 2002; Farrero et al., 2002; Roup, 2004). Choi and Mueller (1992) suggested that performance measurements should utilize financial and non-financial indicators. This study utilized five major dimensions—financial performance, logistical support, service level, learning and innovation, and risk control—to establish an equipment risk-management assessment system (Fig. 1).

3. Construction of the proposed equipment risk assessment model for the petroleum industry

To establish a model for evaluating equipment risk management, this study presents the following three-step procedure – constructing the preliminary assessment indicators, revising assessment indicators, and establishment of assessment model (Fig. 2).

3.1. Constructing the preliminary assessment indicators

After identifying the industrial characteristics of the petrochemical industry and examining domestic and international literature, this study developed the following five dimensions: financial performance, logistical support, service level, learning and innovation, and, risk control. These five dimensions encompass 13 strategic subjects and 78 key measurement indicators. These indicators have the following focuses.

3.1.1. Financial performance dimension

An enterprise attempts to maximize profit and growth. Financial strategies and appropriate criteria are available at various stages in corporate lifecycles. Based on industrial characteristics and relevant literature, this study uses cost control, cost reduction and profit creation (three items) to generate 15 performance measurement indicators.

3.1.2. Logistical support dimension

Because the petrochemical industry is closely linked to the livelihood of a nation, the petrochemical industry has invested in numerous enterprise resources in recent years to ensure equipment reliability. Operational risk resulting from sudden equipment breakdown can thereby be eliminated. This study analyzes inventory management, contracted manpower, and purchase management (three items) to generate 18 performance measurement indicators.

3.1.3. Service level dimension

Facilities in the petrochemical industry require constant maintenance and repairs to optimize performance and reduce breakdown risk. Enterprises must therefore seek help from contracted manufacturers to perform constant maintenance and repairs. This study primarily analyzes contracted manufacturer management and internal service satisfaction (two items) to develop 14 performance measurement indicators.

3.1.4. Learning and innovation dimension

To face challenges associated with economic liberalization and globalization, enterprises must increase the investment of intangible assets via prospective applications such as strengthening staff function, enhancing the capabilities of information systems and passing on maintenance experience. This study analyzes improvements to key functions, knowledge management and its application (two items) to develop 13 performance measurement indicators.

3.1.5. Risk control dimension

Given the situation of limited resources and increased competition, enterprises must realize that risk control is the key to future profit, but still requires close coordination with the other four dimensions to achieve success. This study primarily uses key information mastering, risk planning and assessment, and equipment control capability (three items) to generate 18 performance measurement indicators.

3.2. Revising assessment indicators

Experts in manufacturing department, maintenance department, management department and external experts/scholars of equipment risk management were asked to identify whether or not each proposed dimension, strategic subject and indicator was appropriate for evaluating the performance of equipment risk

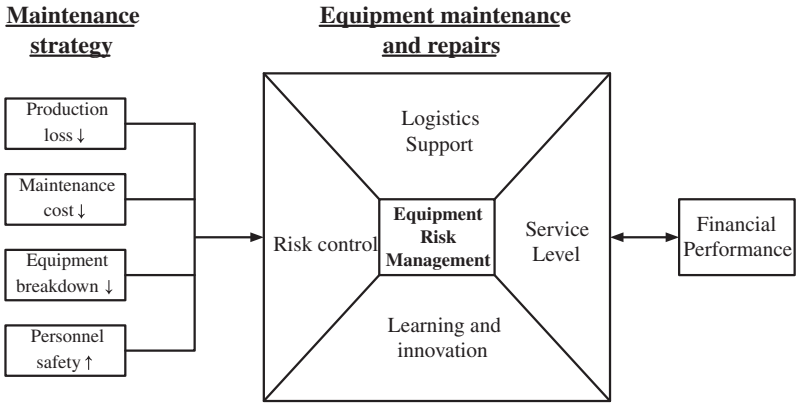

Fig. 1. The construct of assessment model for equipment risk control.