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Optimization of supply chain based on macro ergonomics criteria: A case study in gas transmission unit

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ABSTRACT

Natural gas supply chain is potentially susceptible to high costs caused by horrible outcomes such as explosion, injuries and mortality of workers, greenhouse gas emissions and production process halt. Macro-ergonomics analysis and design method is an efficient methodology which can lead to an overall gas supply chain optimization. This study presents a novel concept of macro-ergonomics analysis and design method, in form of a multi-objective mathematical model. Problem objectives include reducing operating and transportation costs, environmental costs, and delay costs besides increasing in value of purchasing from importers. Results of the mathematical model in form of a multi-objective optimization, were obtained through augmented ε-constraint method. The model have been applied this in the supply chain of Iran gas transmission which is one of the country's most sensitive and vital industries. Results of the model were analyzed after implementing the suggestions of macro-ergonomics approach to evaluate the considered supply chain performance, and the result shown 10% reduction in operating costs per unit. This study can be entitled the first research which evaluates the macro-ergonomics analysis and design method trough mathematical model supply chains.

1. Motivation and significance

With increasing competition in the business world and the emergence and development of new technologies and approaches and management, production and information philosophies have led many supply chains to increase the level of service, quality and cost reduction. Effort to increase the quality and reduce costs is necessary for survival and activity in this competitive environment. On the other hand, the focus on reducing costs and implementing new approaches without principle method has burdensome consequences that will follow more costs. As a result, consideration of organizational, technical and environmental issues in the supply chain is necessary before making any decision. Taking into account human factors and factors based on macro-ergonomics in the total supply chain is vital in aligning the management goals and personnel goals in a supply chain. It is worth mentioning that due to the special features of gas supply chain and the importance of safety issues in gas transmission network, the issues concerning macro-ergonomics and gas supply chain are addressed together.

2. Introduction

Considering the ergonomics and macro-ergonomics issues in the supply chain of gas transport is very important. Macro-ergonomics is called the human—organization-environment-machine interface, considers all four components of technical - social systems. Although, it's main focus is on the relationship between organizational design and the technology used in the system, so that the performance of the system – human is optimized.

(Hendrick, 2002, 1997, 1995). Conceptually, the term macro-ergonomics has a top-down approach to design organization and work systems as well as human - machine and human - environment interfaces. Although many efforts have focused on studying methods to prevent incidents in major hazard plants, mishaps still occur because of various technical and human failures and random natural events. It seems that unexpected disturbances not being absorbed by the system and leading to catastrophes are unavoidable even under good risk management; this seems to be true especially today with the more complex systems. (Dinh et al., 2012). In addition, the certification and implementation of occupational health and safety management systems have become a priority for many organizations. To investigate the status of implementing

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occupational health and safety management systems (Chen et al., 2009).

Gas industries are considered as mother industries, which according to the country's vast oil and gas resources and the government's emphasis on the transition from single-product economy based on crude oil exports to economies with different industrialized products, the industry can play a major role in economic progress. The cheap and abundant raw materials, creating job opportunities, transfer of advanced technology, and above all significant added value has caused to pay more attention to the industry in the economic and social development plans. Therefore, since the gas industry is one of the most important industries in the country, consistent and correct functioning in it is of high importance, so that pausing its performance may cause damage with high costs. Thus, preventing the emergence of dysfunction is very important in it. On the other hand, because of the need of process industries to humans, macro-ergonomics and ergonomics knowledge has important applications in these systems. Environments, in which specific processes (e.g. chemical processes) flow and the components with dynamic nature can be seen in them and are complex and fully automated systems, they should be careful in terms of safety and economy. The safety systems and economic costs are associated with human performance and organizational designs in these systems. A close correlation exists between the health, safety, environment and ergonomic factors. Inadequate design between humans and machines can reduce immunity. Inadequate design of system will result in management error. Management error and workplace damaging factors can lead to human error and safety outcomes thus resulting in environmental risks. Unexpected events in technological systems can occur in different contexts. In recent years, various methods and approaches were presented to deal with unexpected events with a focus on systems management applications. Definition and implementation of an isolated system cannot ensure the preservation and promotion of safety. Therefore, it is necessary to create an integrated system for continuous monitoring and control of unexpected events. A close correlation exists between the health, safety, environment and macro-ergonomics factors. Inadequate design between man, machine and the environment can lead to decreased immunity. Inadequate management system will result in management error. Management errors and workplace damaging factors can lead to human error and safety outcomes that will result in environmental risks. Thus we find that health, safety, environment and macro-ergonomics systems require continuous and systematic efforts to achieve sustainable success. Different industrial managers attempt to improve their interactions with staff and maintaining their health, safety and satisfaction to increase their profitability.

This study evaluates and optimizes the supply chain according to macro-ergonomics criteria. Therefore, using the method of analysis and the macro-ergonomics design, a plan for supplying and transferring the gas supply chain in the form of a mathematical model is presented to reduce transport and operations costs, reduce environmental pollution, reduce costs of gas delay and improve the value of gas purchase from importers. Also the work features and man – machine interfaces, environmental and user-related factors and the process of information flow are reviewed in sensitive compressor stations that have a strong impact on supply chain function from macro-ergonomics perspective. Then, taking into account the objectives of supply chain and macro-ergonomics criteria, the overall structure of the supply chain is optimized by providing a mathematical model. Expressing the holistic macro-ergonomics approach, bringing quality standards of macro-ergonomics in the form of mathematical model, modeling the problem by considering different functions based on macro-ergonomics standards and supply chain and applying this model in the supply chain of Iran gas transmission which is one of the country's most sensitive and vital industries and just investment in these industries reduces unpleasant event and prosperity and improvement of the quality of a country's economy are the innovations of this research.

3. Literature review

3.1. Studies in the field of natural gas supply chain

Energy is one of the most important resources for social and economic development of any country. Natural gas is considered as one of the cleanest and most economical energy. Across the world, the need for natural gas is increasing along with the development of industries and agricultural activities. Thus, the natural gas industry is considered as one of the major industries and plays an important role in the economy of a country. Countries that are rich in natural gas, take many economic advantages from the development and planning the natural gas networks. While the cost of investing in the gas transmission network is large, even small improvements in productivity and system planning reduces cost a lot.

Many issues in this industry have attracted the scholars' attention, including generation, transmission and distribution by natural gas networks. In gas supply networks, gas is extracted from wells and refined at the refinery. Then the processed gas is transmitted to the cities, power plants, storage reservoirs and exports via pipelines. Cities, power plants, storage reservoirs and export and import expenses are linked together as pipelines. Thus, a direct flow is required between the path sections. Costs of export and import are points that connect the countries natural gas networks. Storage reservoirs have a dual role. They receive the gas as storage points and then gas is extracted from them as the production points when the demand is greater than supply, or when the operating cost is high (Nikbakht et al., 2012).

Most efforts in the field of gas pipeline network optimization is done in the field of their performance optimization, few studies have been conducted to use optimization methods in finding optimal design of these systems. Wong and Larson (1968) examined the optimization of a tree-structured network of gas transmission by considering connection networks through dynamic planning. Genetic algorithm optimization method was applied for the first time by Goldberg and Richardson (1987) to optimize the performance of pipelines. Letniowski (1993) has modeled the compressor station in the gas transmission network. Furey (1993) have used sequential quadratic programming based algorithm for the management of the gas transmission network, including reduced fuel consumption, increased flow of resources and keeping the gas flow at the permissible level. Mohitpour et al. (1996) have used dynamic simulation for designing and optimization of system of pipelines. Wolf and Smeers (2000) have used developed simplex method to reduce the cost of gas transmission network under the non-linear pressure constraints, and material balance equation and pressure range. Wu et al. (2000) have examined the problem of reducing the cost of fuel consumed by the compressor stations using relaxation method. Rios-Mercado et al. (2002) have used a reduction technique for optimization problems in natural gas transmission networks. Borraz-Sanchez and Rios-Mercado (2005) have presented a hybrid innovative algorithm to reduce the fuel cost in the gas transmission system in a cycled network. Their innovative method has two repeatable phases. In the first phase, the gas flow variables are valued and then the optimum value of pressure variables is determined and in the next phase, the pressure variables are valued and then the optimal value of gas flow variables is determined by Tabu search method. Kabirian and Hemmati (2007) have examined the type, location, and the plan