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Green supply chain management, reverse logistics and nuclear power generation

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Abstract

Built on the concepts of green supply chain management (G-SCM), this paper presents a multi-objective optimization programming approach to address the issue of nuclear power generation. In this study, a linear multi-objective optimization model is formulated to optimize the operations of both the nuclear power generation and the corresponding induced-waste reverse logistics. Factors such as the operational risks induced in both the power generation and reverse logistics processes are considered in the model formulation. Numerical results indicate that using the proposed approach, the induced environmental impact including the corresponding costs and risks can be improved up to 37.8%.

Keywords: Green supply chain management; Nuclear power generation; Reverse logistics; Multi-objective optimization

1. Introduction

Although nuclear power generation has raised worldwide concerns on environmental and safety issues, e.g., the Chernonyl event in Russia and the Three Mile Island (TMI) accident in the US (Strupczewski, 2003), it is undeniable that such an energy resource remains vital in dominating the trends of global electric resource allocation and utilization. Nowadays, nuclear energy accounts for 17% of the worldwide power generation. However, according to the analysis of Kido (1998), due to the rapid growth of economy in Asia, the nuclear power capacity in Asia may rise from 17 gega watts (GW) in 1995 to 67 GW by 2010, sharing the corresponding worldwide capacity from 5% to 15%. In Lake (2002), it is further claimed that the world electricity demand may double in the next 20–25 years and possibly triple by 2050. And thus, it is inferred that nuclear power generation can be viewed as the primary technology capable of satisfying the future worldwide electricity demand without worsening greenhouse gas emissions. Such an argument can be further proven in the case of Kyoto agreement being applied worldwide. Similar arguments can also be found in Ponomarev-Stepnoi

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(1997) which speculates that nuclear power may still dominate the world electricity resources in the 21st century as new nuclear power technology being developed to mitigate the induced negative effects.

Despite the importance of nuclear power generation in addressing the issue of the growing worldwide electricity demand, there appears to be an urgent need for developing a green supply chain-based operational methodology to systematically manage the entire lifecycle of the corresponding product, including the generated nuclear power and induced wastes. According to the statistical reports in Taiwan, the aggregate radioactive waste accumulated in the past 30 years induced by three existing nuclear power generators has reached to 9000 tons. Due to increasing dependence on nuclear power generation, South Korea may face more serious nuclear waste problems up to 2015 in which there will be a total of 26 nuclear reactors in operation (Hwang et al., 2003). Expanded from such numerical results, it is inferred that under the existing condition of more than 400 nuclear power generators in operation around the world, the global nuclear wastes accumulation problem may become worse if it is not integrated with efficient green-driven solutions. Accordingly, the measures of integrating all the logistics operational procedures for nuclear power from cradle to grave in a comprehensive operational framework for green supply chain management (G-SCM[1]) is vital to the operations of nuclear power generation and induced nuclear waste management. Supportive arguments can also be found elsewhere (Stock, 1998; Sheu et al., 2005).

Nevertheless, to our knowledge, the corresponding G-SCM based integrated logistics measures used in managing simultaneously nuclear power generation and induced wastes are never found in previous literature. Instead, most of the early literature may be limited to exploring the measures of either assessing the potential operational risks or managing the induced nuclear wastes. Some typical methods are illustrated below.

By incorporating the coefficient of risk aversion into the expected utility approach, the model proposed in Eeckhoudt et al. (2000) appears promising to assess the external costs of nuclear fuel cycles imposed on society and the environment under various operational conditions of nuclear power generation. Similarly, considering the corresponding influencing factors and induced environmental risks, Margulies (2004) proposed a risk-optimization programming approach to determining the location of nuclear power generators. As further pointed out in Cowing et al. (2004), the short-term tradeoffs between productivity and safety often exist in the operation of nuclear power generation, and thus should be taken into account to optimize the long-term system performance. In addition, Lee et al. (2000) proposed a Life Cycle Assessment (LCA) based methodology to evaluate the environmental impact of nuclear power generation in Korea, where a respective radiological impact assessment procedure is incorporated to enhance the validity of the analytical results. Apparently, their LCA-based approach provides a cradle-to-grave environmental assessment framework serving to quantify the corresponding environmental effects of nuclear power generation induced in its life cycle.

In contrast to the aforementioned literature aiming the evaluation scope, a few investigations have been devoted to the issues on managing the induced nuclear wastes. In ReVelle et al. (1991), a synthesized linear programming method is proposed to manage the reverse logistics flows of spent nuclear fuel, where both the 0–1 integer and multi-objective optimization models are synthesized to determine waste storage facilities as well as the shortest paths for shipping. By characterizing the properties of nuclear wastes, Hawickhorst (1997) claimed that the effective management of these nuclear wastes is the prerequisite for the operation of a nuclear energy system, where the operational case of Germany is illustrated. Some other hazardous-waste reverse logistics methods that are not directly related to nuclear wastes can also be found in the related literature (Koo et al., 1991; Stowers and Palekar, 1993; Nema and Gupta, 1999). However, those previous studies may be still limited to the scope of reverse logistics without considering its effect on the operational performance of the corresponding supply chain management.

In view of the significance of incorporating the induced environmental risk effects in addressing the operating problem of nuclear power generation as well as the limitations of previous studies, we propose a G-SCM based integrated logistics methodology to investigate the potential advantages of a G-SCM based nuclear

[1] One typical example for illustrating the practical use of G-SCM is that in Europe, some industrial countries have enforced environmental legislation charging manufactures with the social responsibility for reverse logistics flows, including used products and manufacturing-induced wastes (Robeson et al., 1992; Fleischmann et al., 2000). Therein, subjects about green product design, used product recycling, waste disposal, and manufacturing-induced pollution alleviation, are addressed in a comprehensive operational framework.