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A fuzzy AHP–GP approach for integrated production-planning considering manufacturing partners

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ABSTRACT

Most manufacturing companies cooperate with manufacturing partners in order to have flexible usable capacities to meet variable customer demand. In this environment, evaluations of manufacturing partners and integrated production-planning have become a critical issue. For integrated production-planning for all local manufacturing sites and manufacturing partners, the company should first evaluate the manufacturing partner, and then should decide how to allocate the production quota among internal facilities and manufacturing partners. In this paper, we propose a fuzzy analytic hierarchy process (AHP)–goal programming (GP) approach to solve this integrated production-planning problem. The fuzzy AHP is utilized to determine relative weights of manufacturing partners, while the GP is used to formulate the integrated production-planning problem. The proposed approach is illustrated by an example adopted from a TFT-LCD manufacturing firm.

1. Introduction

Cooperation with manufacturing partners in order to have flexible usable capacities to meet customer demand has become more important than ever. Flexible capacity enables companies to rapidly respond to changes in demand and to avoid lost sales originating from production shortages. In this environment, the selection of appropriate manufacturing partners and the integration of production-planning that considers the selected manufacturing partners have become crucial issues. For integrated production-planning among all local manufacturing sites and manufacturing partners, the company should evaluate the manufacturing partner first in terms of criteria such as price, quality, on-time delivery rate, reputation, etc. Next, the company needs to decide the production volumes of both local manufacturing sites and the selected manufacturing partners by considering the bill-of-material (BOM) structure required to meet the demand quantity of the final product. Each manufacturing site produces the specified components and has a fixed production capacity. In addition, manufacturing partners that are capable of satisfying the quality and technology requirements have a fixed production capacity for production support of components in the BOM, except for the final product.

The problem considered in this paper can be found in most general assembly industries, including a thin-film transistor liquid crystal display (TFT-LCD) manufacturing industry. The TFT-LCD manufacturing process has three basic stages: thin-film transistor (TFT) fabrication, liquid crystal (LC) assembly, and the module assembly process. The TFT fabrication process is very similar to semiconductor wafer fabrication, but is much simpler. The LC assembly process consists of many steps to construct the TFT and color filter panels. The module assembly process is the last stage of TFT-LCD manufacturing processes, where the TFT-LCD panels passed from the LC assembly process are put together with the other necessary parts to complete the final TFT-LCD product. The module assembly process requires approximately 16 distinct, essential parts, most of which are supplied by manufacturing partners. In addition to the module assembly process, the LC assembly process also requires the capacity for several internal assembly steps according to the scheduled production plan of a successful module assembly process.

Thus, the appropriate allocation of production volumes to various manufacturing partners in both assembly processes directly affects the generation of a good production plan for whole TFT-LCD manufacturing processes. In other words, the more reliable manufacturing partners should take more production volume in the integrated production-planning. Our motivating industry, the TFT-LCD manufacturing process, is as shown in Fig. 1.

However, the evaluation of manufacturing partners is not a simple task since it is a decision-making problem with multiple criteria and a high degree of fuzziness and uncertainty in practice. As in many real-world evaluation problems, decision makers prefer to convey their opinions with verbal expression, even though there are some quantitative factors (Güngör, Serhadlıoğlu, & Kesen, 2009). Thus, we need to adopt a means such as the fuzzy set theory to translate verbal expressions into numerical ones, and we must

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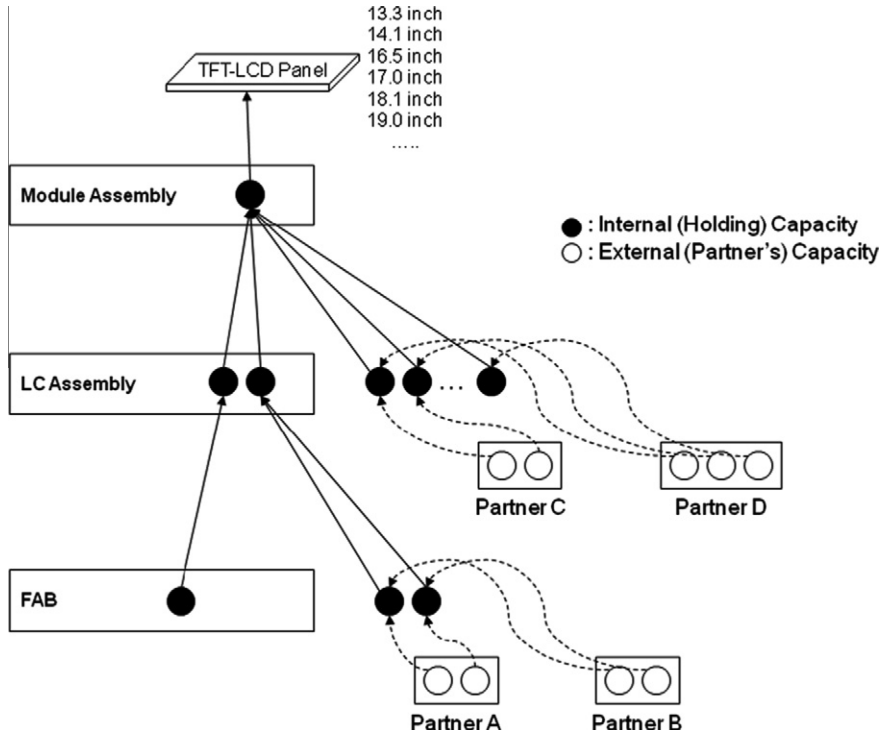

Fig. 1. TFT-LCD manufacturing environment shown with manufacturing partners.

evaluate the relative importance (weights) of each manufacturing partner in order to generate an optimized and integrated production plan with the preferred manufacturing partners.

The objective of this paper was to propose a fuzzy analytical hierarchy process (AHP) and goal programming (GP) hybrid approach for integrated production-planning considering manufacturing partners (IPPMP). To generate the relative weights of each manufacturing partner, a fuzzy AHP was utilized. In this fuzzy AHP method, linguistics values expressed in triangular fuzzy numbers were used, and the α-cut method and the index of optimism were adopted to consider the confidence level of the judgments and the attitude of the decision-maker, respectively. In addition, the geometric mean method was used for defuzzification. Once the relative weights of all manufacturing partners were determined, we then developed a GP-based integrated production planning model that has two goals: (1) to minimize the total cost; and (2) to minimize the allocation of production volumes to the manufacturing partners with the lowest weights.

The related research can be classified into two categories: (1) fuzzy AHP for supplier evaluation; and (2) production-planning considering manufacturing partners.

As the literature on the general supplier evaluation is extensive and too broad to be fully covered here, we focused on the fuzzy AHP for supplier evaluation that is directly related to our proposed model. The AHP is a systematic method widely used for decision-making problems with multiple criteria and alternatives and was first developed by Saaty (1980). As for the literature on the traditional AHP and its applications including supplier selection problems, Vaidya and Kumar (2006) published a review paper that summarizes the extensive applications of AHP in terms of application areas. Although the traditional AHP requires precise judgments from decision makers, it is not always possible to do that in practice (Wang & Chin, 2008). In the real world, decision making in supplier selection includes a high degree of fuzziness and uncertainties (Guneri, Yucel, & Ayyildiz, 2009). In addition, decision makers very naturally provide uncertain answers rather than precise values, and it is difficult to transform qualitative preferences to point estimates (Lee, Kang, & Wang, 2005). To overcome this difficulty, fuzzy judgments have been suggested, and the fuzzy AHP has been applied in the supplier selection problem. Kahraman, Cebeci, and Ulukan (2003) used the fuzzy AHP for supplier selection with three criteria, and Chen, Lin, and Huang (2006) addressed the supplier selection problem by applying linguistic values to assess the ratings and weights of supply chain criteria by using a hierarchy multiple criteria decision-making model. Chan and Kumar (2007) and Chan, Kumar, Tiwari, Lau, and Choy (2008) developed the fuzzy AHP approaches for global supplier selection where international issues such as political-economic situation, geographical location, and risk factor are considered. More recently, Chamodrakas, Batis, and Martakos (2010) introduced a two-stage method for supplier selection. In the first stage, satisficing is used to prune the supplier search space. The fuzzy AHP is utilized in the second stage to produce a final ranking order of suppliers.

For production-planning models considering manufacturing partners, most of the past research focused on external integration with retailers or distributors and did not consider the internal integration of production with manufacturing partners. In addition, the production-planning problem of their research usually focused on a single-level product structure without considering multi-level BOM structures. More importantly, the evaluation of manufacturing partners that utilized relative weights among partners to perform production-planning has not been the focus of the past research. Cohen, Fisher, and Jaikumar (1989) suggested a standard management model for a corporation that produces and sources globally. Arntzen, Brown, Harrison, and Trafton (1995) developed a large mixed integer program to determine a production–distribution strategy for a global company. Frederix (2001) developed an efficient algorithm to plan and schedule the resources of a semiconductor enterprise under the global manufacturing environment where the geographically dispersed production facilities concentrate on core technologies and need to make a make-or-buy decision considering manufacturing partners. Ip, Yung, and Wang