A Multi Objective Model For Fish Processed Production Planning Under Uncertainty

Sawaluddin#1, Herman Mawengkang#2

Graduate School of Mathematics, University of Sumatera Utara
North Sumatera, Indonesia

***Abstract*— In Indonesia one of the very important factor for economic development is marine fisheries. Besides being the most affordable source of animal protein in the diet of most people in the country, this industrial sector could contribute environmental degradation. This paper addresses a multi-objective stochastic programming model of the sustainable production planning of fish processed products. The model takes into account conflicting goals such as return and financial risk and environmental costs. The uncertainty comes from the reliability of financial risk. Starting from it two single objective models are formulated: a maximum expected return model and a minimum financial risk (waste penalties) model. We transform the stochastic programming model into a deterministic optimization model using covariance approach.**

***Keywords*— Environmental Production Planning, Stochastic Programming, Modelling, Financial risk.**

I. Introduction

Indonesia consists of thousand of islands. Therefore it is reasonable that arine fisheries could play as an important role in the economic development of the country. Another important aspect besides being a primary source of animal protein, this industry could provide employment to people who live at coastal areas. Fisheries industrial sector can be classified into three different parts, i.e., open sea fishing, fish cultivation and processed fish. This paper is focusing on the latter sector. Generally the processed fish industry in Indonesia can be found at the coastal area. There are a lot of varieties of fish processed can be produced, such as smoked fish, salted fish, crunchy bashed of fish, fish bowl, terrain (fish preserved), etc. The management of fish processed industry is still dominated by the local small traditional business, using conventional management strategy. Therefore they do not have any knowledge of management in handling the production waste.

In terms of mathematical model production planning problems can be broadly classified into two classes: deterministic models and stochastic models. In deterministic models the data are assumed to be known. When the data of the model are uncertain, then we have a stochastic model. Although various human judgment based and quantitative models have been developed to forecast these variables with uncertainty such as demand, these deterministic models typically end up solving “mean-value” or “worst-case” problems The solution to such “worst-cast” or “mean-value” problems are often inadequate – large error bounds arise when one solves “mean value” problems and “worst-case” formulations that can produce very conservative and expensive solutions ([2]). Without considering uncertainty, the deterministic production planning models, though widely studied in the literature, are less acceptable and deployed in practice.

In today’s world consumers, companies and governments have increased their attention towards the environment. Increased exposure in the media on environmental issues in conjunction with the escalating increase in the environmental resources depletion, human toxicity levels and ecosystem quality deterioration have made our entire society more aware of environmental damage. Companies, in turn, are investing more in the assessment of the environmental impact of their products and services.

Industrial waste handling is the final and critical step for industrial pollution control. It is also an important issue to cleaner production and sustainable development. Industrial eco-systems are the environmental friendly systems for industrial waste recycling, resembling the food chains, food webs and the nutrient recycles in natural environment ([10]). They are much more environment friendly compared to other waste treatments such as incineration, solidification and landfill.

In normative and qualitative way, these problems have led to the concept of trade-offs and efficient frontiers for business and the environment ([3], [6]). The rationale is to determine the set of solutions in which it is not possible to decrease environmental burden or increase total environmental quality of each environmental category, unless increasing the costs. In optimization model point of view, this type of problem can be formulated as a multi-criteria optimization model. However, despite the extensive existing literature in the field of multi-criteria programming, there is not much developed on determining such a frontier or assessing the trade-offs in sustainable logistics networks. In this paper we intend to address an approach that is sounded to capitalize the decision maker’s most effective cognitive capabilities: visual representation. In order to explore the efficient frontier in feasible time (for the intractability of determining all extreme efficient solutions in a multi-objective linear program, see in [15] and [16].

In every seafood production process, inputs are used to create a processed product or commodity. Inevitably, some inputs are not fully used and are released into the environment in forms that may be considered pollutants or waste. Whenever the level of waste exceeds the environment’s ability to absorb and process these discharges, environmental risks develop.

Regarding to the importance of the sustainable production planning of fish processed creates a stimulus for the research in the mathematical programming model. Refference [18] propose a multi objective model for solving sustainable production planning, which take into account environmental constraints. This is a general production model. Refference [17] use an optimization model approach to solving production planning of crude palm oil in order to reduce fresahwater usage. The production of seafood particularly fish is a complex problem, due to the influence of processing variables and environmental impacts. [18} address a model using fuzzy expert system to solve the problem. Recently, [19] propose a linear prograsmming model for production planning. But they do not include environmental factor in their model.

Due to the fact that the sustainable production planning of fish processed consists of several objectives, such as, economics, environmental quality and environmental risk, in this paper we propose a multi objective model for solving such problem. Further more for the environmental risk we impose a probability constraint in such a way to make the environmetal risk reliable. Therefore chance constraint programming would be the appropriate model for that situation.

II. Model Formulation

Fish and its processed products are the most affordable source of animal protein in the diet of most people. In Indonesia, most of the fish processed industries are found at the coastal area. In these industries fish are processed traditionally. There are eight kinds of fish product to be produced by the community, namely , dried fish, salted fish, BBQ fish, pindang fish, smoked fish, fish preserved, pressed fish, and fish bowl.

The fish processed industry under investigation is located at the eastern coastal area of North Sumatra province of Indonesia. The industry run by the community of that area has to make a production plan for these eight fish processed products to fulfill market demand.

We formulate the sustainable production planning model of fish processed that take into account environmental constraints. A general multi-objective programming problem is formulated in which the objective functions are the expected return of the production plan and the penalties for the case when the cumulative effect of each emission overcome some environmental levels and the financial risk of the production plan. The manager tries to find a production plan that maximize the expected return of it, minimize the pollution penalties and satisfies the environmental constraints.

Suppose that the traditional plant manager of fish has the possibility to manufacture eight kinds of fish products, T_1, T_2, …, T_8. For all i =1, 2, ..., 8, denote by c_i the selling price of a product of type T_i. Note that all c_i are random variables. The manufacture of a product generates none, one or several waste discharge F_1, F_2, …, F_n and requires p resources R_1, R_2, …, R_p.

Denote by b_{ij} the amount of waste discharge F_j when is manufactured a product of type T_i and by c_{ik} the amount of resource R_k required for manufacturing a fish product of kind T_i. Denote by r_k the maximum availability of resource R_k. Note that b_{ij} and c_{ik} are nonnegative numbers. The manager wants to invest a sum M of money in the range $[M_1, M_2]$ in order to manufacture products of types $T_1, T_2,\ldots,T_n$. He desires to obtain a production plan $\mathbf{x} = (x_1, x_2, \ldots, x_n)$ that gives him a maximum expected return, a minimum risk for the environment waste and a minimum financial risk.

In this paper the waste risk is measured by the penalties paid by the manager for the environment waste. Denote by d_{j1} the desirable or target waste level for the waste discharge F_j. Denote by d_{j2} the alarm level of waste for the waste discharge F_j. Denote by d_{j3} the maximum acceptable limit of pollutant for the waste discharge F_j. In this case $0 \le d_{j1} \le d_{j2} \le d_{j3}$ for every j = 1, 2, ..., m. A small overcome of the level d_{j1} represent no danger for the environment. It represents only a warning that the waste process had already began. A small overcome of the level d_{j3} represent a warning that the waste process may have consequences for the environment. An overcome of the level represents a warning that the waste process had already produced bad consequences for the environment and urgent measures must be taken in order to stop the process.

Let $\mathbf{x} = (x_1, x_2, \ldots, x_8)$ be the output plan of fish plant. Here x_i represents the number of products of fish kind T_i, i =1, 2, ..., 8. Denote by p_i the production cost of a product of type T_i and by q_i a minimum quantity of products of type T_i that should be produced. The value of p_i are positive real numbers and q_i are natural numbers for all i =1, 2, ..., 8. The production cost for the production plan $\mathbf{x} = (x_1, x_2, \ldots, x_8)$ is equal to $\sum_{i=1}^{8} p_i x_i$. We shall call $\mathbf{q} = (q_1, q_2, \ldots, q_8)$ the vector of demand. If a is a real number we shall denote by a_+ the positive part of a, that is:

$$a_+ = \max(a,0) = \frac{|a| + a}{2}$$

We shall consider that, the environmental penalty paid in the case the output plan $\mathbf{x} = (x_1, x_2, \ldots, x_8)$ is applied is proportional to the amount of pollutant that overcomes the waste level. Consequently in the case of waste discharge and waste level it is equal to

$$a_{js}\left(\sum_{i=1}^{n} b_{ij}x_i - d_{js}\right)_+$$

We denoted by a_{js} the proportionality factor from the environmental penalty. The overall environmental penalty will be in this case

$$f_1(\mathbf{x}) = \sum_{s=1}^{2}\sum_{j=1}^{m} a_{js}\left(\sum_{i=1}^{8} b_{ij}x_i - d_{js}\right)_+ \qquad (1)$$

The idea of considering a desirable waste level and environmental penalties proportional to the amount of pollutant that overcome the waste level goes back to [18]. The manager must take into account environmental constraints. In our paper we shall consider constraints that impose some bounds on the expected amount of waste discharge:

$$\sum_{i=1}^{8} b_{ij} x_i \le d_{j4} \quad j = 1, 2, ..., m \tag{2}$$

Here we denoted by d_{j4} a number smaller or equal than d_{j3}. It measures the aversion against a polluted environment. The smaller is d_{j4}, the cleaner will be the environment. We shall denote by E_1 the set of all nonnegative vectors $\mathbf{x} = (x_1, x_2, \dots, x_8)$ having integer components that satisfy: the inequalities $x_i \ge q_i$ for all i, the environmental constraints (2) and the resource constraints

$$\sum_{i=1}^{8} c_{ij} x_i \le r_k \quad k = 1, 2, ..., p \tag{3}$$

Denote by σ_{ij} the covariance of the random variables and let $C = (\sigma_{ij})$ be the covariance matrix. We shall define the financial risk of the production plan $\mathbf{x}$ as the variance of the its return $\sum_{i=1}^{8} c_i x_i$. One can easily see that

$$\mathrm{Var}\left(\sum_{i=1}^{8} c_i x_i \right) = \sum_{i=1}^{8} \sum_{j=1}^{m} \sigma_{ij} x_i x_j = \mathbf{x}^T \mathbf{C} \mathbf{x}$$

In order to use efficiently the sum available, the manager tries to find a production plan $\mathbf{x} = (x_1, x_2, \dots, x_8)$ such that it will bring a maximum return, it will minimize the overcome of the waste levels and the financial risk and it will allow him to comply with environmental restrictions.

In order to find such a plan the fish plant manager must solve the following multiobjective programming problem:

$$(\mathrm{S}) \begin{cases} \max \left[\sum_{i=1}^{8} (E[c_i] - p_i) x_i \right] \\ \min \left(\sum_{i=1}^{8} b_{ij} x_i - d_{js} \right)_+ \quad s = 1, 2;\ j = 1, 2, ..., m; \\ \min \left(\sum_{i=1}^{8} \sum_{j=1}^{m} \sigma_{ij} x_i x_j \right) \\ M_1 \le \sum_{i=1}^{8} p_i x_i \le M_2,\ \mathbf{x} \in E_1 \end{cases}$$

There are several approaches for reducing the above problem to single objective programming problems. Two of them are presented in the following.

A. A Minimum Financial Risk Model

In the minimum financial risk problems the manager tries to minimize the financial risk taking into account the following restrictions:

- The production plans satisfy the environmental and resource conditions (2) and (3), that is $\mathbf{x} \in E_1$.
- The sum M invested in the production plan is in the range $[M_1, M_2]$.
- The expected return of the production plan is greater than a given value W.

The model is the following:

$$(Q_1) \begin{cases} \min \left(\sum_{i=1}^{8} \sum_{j=1}^{m} \sigma_{ij} x_i x_j \right) \\ f_1(\mathbf{x}) \le v \\ \sum_{i=1}^{8} (E[c_i] - p_i) x_i \ge W \\ M_1 \le \sum_{i=1}^{8} p_i x_i \le M_2,\ \mathbf{x} \in E_1 \end{cases}$$

Here W is the parameter that controls the expected return of the production plan and ν is the parameter that controls monetarily the penalties paid for pollution.

B. A Maximum Expected Return Model

In the maximum expected return problem the manager tries to maximize the expected net return taking into account the following restrictions:

- The production plans satisfy the environmental and resource conditions (2) and (3), that is $\mathbf{x} \in E_1$.
- The sum M invested in the production planning is in the range $[M_1, M_2]$.
- The financial risk is smaller than a given value τ

$$(Q_2) \begin{cases} \max \left[\sum_{i=1}^{8} (E[c_i] - p_i) x_i - f_1(\mathbf{x}) \right] \\ \sum_{i=1}^{8} \sum_{j=1}^{m} \sigma_{ij} x_i x_j \le \tau \\ M_1 \le \sum_{i=1}^{8} p_i x_i \le M_2,\ \mathbf{x} \in E1 \end{cases}$$

Now the problem (Q_1) and (Q_2) are single objective programming problems.

III. STOCHASTIC MODEL

The parameters v and W in constraints problem Q_1 represent the uncertain parameter of our problem. If we ignore the uncertainty and replace these random quantities by representative values, such as their mean values, we can solve a deterministic problem DP to obtain a simple solution for this problem. This deterministic solution will be helpful as a benchmark. There are two other ways to handle uncertainty that for this problem lead to the solution of a single deterministic problem (DP): chance constrained programming and robust optimization. The solution of this fish processed production planning problem through other methods of representing uncertainty, such as stochastic programming and Markov-decision processes require more involved solution procedures and will not be explored in this paper.

In chance constrained programming (CCP) we assume that the parameters v and W are unknown at the time of planning but follow some known probability distributions. We assume they are uniformly and independently distributed. We let α_D and α_T represent the confidence level of the chance constraints defining the unmet demand at each node and the arrival time of each vehicle at each node respectively. Thus, the constraints with stochastic parameters must hold with these given probabilities. For a given distribution on v *and* W we can rewrite the constraints in the chance constrained fashion with levels α_p and α_r as follows:

$$P[f_1(x) \le \upsilon] \ge 1 - \alpha_p$$

$$P[\sum_{i=1}^{n}(E[c_i] - p_i)x_i \ge W] \ge 1 - \alpha_r$$

A. Chance-Constrained Programming

A generic chance-constrained optimization problem can be formulated as

$$\min_{x \in X} f(x) \text{ subject to } \Pr\{G(x,\xi) \le 0\} \ge 1 - \varepsilon, \qquad (4)$$

where $X \subset R^n$ represents a deterministic feasible region, $f: R^n \to R$ represents the objective to be minimized, ξ is a random vector whose probability distribution is supported on set $\Xi \subset R^n$, G : $R^n \times R^d \to R^m$ is a constraint mapping, 0 is an m-dimensional vector of zeroes, and $\varepsilon \in (0, 1)$ is a given risk parameter (significance level). Formulation (4) seeks a decision vector x from the feasible set X that minimizes the function $f(x)$ while satisfying the chance constraint $G(x, \xi) \le 0$ with probability at least $1 - \varepsilon$. It is assumed that the probability distribution of ξ is known.

In this case, we require that the reliability requirement be applied to all facilities jointly. One could also consider the individual chance constraints $\Pr\{\xi_i \le x_i\} \ge 1 - \varepsilon_i$, $i = 1, \dots, n$, applied to each facility separately. This leads to a much simpler problem, since $\Pr\{\xi_i \le x_i\} \ge 1 - \varepsilon_i$ is equivalent to $F_i^{-1}(x_i) \ge 1 - \varepsilon_i$, where F_i is the cumulative distribution function (CDF) of ξ_i. Note, however, that in order to ensure the joint chance constraint by enforcing the individual chance constraints, the corresponding risk parameters ε_i should be considerably smaller than especially when n is large.

The approach for solving the problems in which it is assumed that the distribution of ξ is such that checking feasibility is easy, and the resulting feasible region is convex. A classical example of this case is when $G(x,\xi) = v - \xi^T x$ and ξ has a multivariate normal distribution with mean μ and covariance matrix Σ. Then for $\varepsilon \in (0, 0.5)$,

$$\left\{x \in R^n : \Pr\{\xi^T x \ge v\} \ge 1 - \varepsilon\right\} = \left\{x \in R^n : v - \mu^T x + z_\varepsilon \sqrt{x^T \Sigma x} \le 0\right\},$$

where $z_\varepsilon = \Phi^{-1}(1 - \varepsilon)$ is the $(1 - \varepsilon)$-quantile of the standard normal distribution. In this case, under convexity of X, the chance-constrained problem reduces to a deterministic convex optimization problem.

IV. Conclusions

Managing business environmental risk in sea food industry consists of making the production process more efficient in such a way as to limit its environmental consequences while increasing profitability. In this paper we present a multi-objective stochastic programming model for managing business environmental risk in a fish processed production planning under uncertainty in demand which consists of making the production process more efficient in such a way to limit the impact of environmental consequences and to meet the investment risk (perceived risk), and then we propose a chance constraint method for solving the problem.

References

[1] Bevc CA, Marshall BK, Picou JS, "Environmental justice and toxic exposure: toward a spatial model of physical health and psychological well-being," *Soc Sci Res.*, vol. 36(1), pp. 48–67, 2007.

[2] Birge JR, Louveaux FV, *Introduction to Stochastic Programming*, New York: Springer, 1997.

[3] J.M. Bloemhof-Ruwaard, H. Krikk, and L.N. Van Wassenhove, *OR Models for Eco-Eco Closed-Loop Supply Chain Optimization,* ser. Reverse Logistics: Quantitative Models for Closed-Loop Supply Chains. 1st ed. Berlin/Heiderberg: Springer-Verlag, 2004, vol 1.

[4] Giannikos I. "A multi-objective programming model for locating treatment sites and routing hazardous wastes," *Eur J. Operational Res.,* vol. 104, pp. 333–42, 1998.

[5] J. Gopal, "The Development of Malaysia's Palm Oil Refining Industry: Obstacles, Policy, and Performance," Ph.D Thesis, University of London and Diploma of Imperial College, England, 2001

[6] G. Huppes and M. Ishikawa, "A framework for quantified eco-efficiency analysis," *Journal of Industrial Ecology*, vol. 9(4), pp. 25-41, 2005.

[7] Jacobs TL and Warmerdam JM, "Simultaneous routing and sitting for hazardous waste operations," *J. Urban Plan Dev.*, vol. 120(3), pp. 115–31, 1994.

[8] Jenkins SH and Bassett G, "Perceived risk and uncertainty of nuclear waste," *Risk Anal.*, vol. 14(5), pp. 851–6, 1994.

[9] Lindell MK and Earle TC, "How close is close enough: public perceptions of the risks of industrial facilities," *Risk Anal.*, vol. 3, pp. 245–53, 1983.

[10] K. Liu and Q. Shyng, "Eco-system in the steel industry," in *Proc. of Inter. Conf. on Cleaner Prod. and Sustainable Development' 99*, Taipei-Taiwan, Dec. 1999.

[11] McClelland GH, Schulze WD, and Hurd B. "The effect of risk belief on property values: a case study of a hazardous waste site," *Risk Anal.*, vol. 10(4), pp. 485–97, 1990.

[12] McCluskey JJ and Rausser GC, "Estimation of perceived risk and its effect on property values," *Land Econ.*, vol. 77(1), pp. 42–55, 2001.

[13] ReVelle C, Cohon J, and Shobrys D, "Simultaneous sitting and routing in disposal of hazardous wastes," *Transport Sci.*, vol. 25(2), pp. 138–45, 1991.

[14] Sjöberg L, "Determinants and consequences of perceived risk," in *Proceedings of Annual Meeting of the Society for Risk Analysis,* 1996.

[15] R.E. Steuer and C.A. Piercy, "A regression study of the number of efficient extreme points in multiple objective linear programming,"

European Journal of Operational Research, vol. 162(2), pp. 484-496, 2005.

[16] R.E. Steuer, "Random problem generation and the computation of efficient extreme points in multiple objectives linear are programming," *Computational Optimization and Applications,* vol. 3, pp. 333-347, 1994.

[17] S. Prasertsan, C. Bunyakan, and J. Chungsiriporn, "Cleaner production of plam oil milling by process optimization," *PSU-UNS International Conf. On Engineering and Environment – ICEE-2005*, Novi Sad, 2005.

[18] Radulescu M, Radsulescu S, and Radulescu C. Z., "Sustainable production technologies which take into account environmental constraints," *European Journal of Operational Research,* vol. 193(3), pp. 730-740, 2009.

[19] Murugan S, Choo J. K., Sihombing H. 2013 Linear Programming for palm oil industry. Int. Journal of Humanities and Management Sciences (IJHMS), Vol.1, Issue 3, 184-187