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POLICY MAKING OF EFFLUENT STANDARD FOR PIG-RAISING INDUSTRY

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ABSTRACT

The main purpose of this paper is devoted to the policy making of effluent standard related to the pig-raising industry in the Taiwan area. Up to the end of 1989, there were about 7.8 million hogs in Taiwan. The total production of hog wastes is quite tremendous, resulting in serious environmental problem. In this study, the application of ELECTRE II algorithm to handle nonquantifiable criteria and discrete alternatives appears efficient. It can be reasonably concluded that the current effluent standard of BOD for hog wastes is appropriate in Taiwan. Since the effluent standard is that for common water bodies, local authorities can specify more stringent standards for some specific protected water bodies.

養豬廢水放流水標準擬定之研究

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關鍵詞：多目標決策分析、放流水標準、生化需氧量、一致性、非一致性、臨界值。

摘 要

本文主旨在於探討臺灣地區養豬廢水放流水標準之擬定。根據農委會調查報告顯示截至民國七十八年十一月底，臺灣地區養豬頭數為七百八十萬頭，估計每日排泄三萬二千噸糞尿，相當於至少三千一百萬人口之排泄量，因此應擬定相關之放流水標準，以維護環境衛生。本文運用多目標理論——ELECTRE法於放流水標準之擬定，結果顯示該法可有效地應用在非量化目標及離散式替代方案；同時驗證出目前國內養豬廢水放流水標準頗為合理。

STATEMENT OF THE PROBLEM

Taiwan's economy growth has increased extraordinarily rapid over the past four decades. Both agriculture and industry flourish rapidly. At the same time, however, the environment has been polluted considerably severely, due to the ignorance of environmental protection in the Taiwan area.

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The environmental quality influences the society's survival and development, and the welfare of the people. During the past few years, environmental concerns have come to play an increasingly important role in Taiwan. In order to meet the needs for pollution abatement and to improve the human living standards, the government of the Republic of China, thus, has turned much attention not only to economic development but also to environmental protection for the long term benefit of the country.

Concerning the agricultural industry, pig-raising industry is a very important enterprise in Taiwan. Up to the end of 1989, there were about 7.8 million pigs as shown in Table 1, nearly 216 head/km^2. The annual exports of hogs approximate 2.81 million head. Of which one-third of hogs are exported to Japan. The pig-raising density is about 6.6 times that of the Japan, 42 times that of the United States, 9.6 times that of the France, 6.4 times that of the Great Britain, and 2.1 times that of the West Germany. On an average daily production of hog manure is 4.12 kg/head, and the amount of water for washing the pens is 3.5 times of that manure (Soong [5]). The hog wastes give a BOD load per pig of 0.11 kg per day, so that the total polluting matter from one pig is about equivalent to that from 3.5 humans (Bartlett [1]).

Traditionally, hog wastes have been deposited on crop land as fertilizer to improve crop yields. In recent years, due to the increase of large-scale hog farms and labor cost along with the low price of chemical fertilizers, the disposal of hog wastes has become a problem of national concern for environmental protection in Taiwan. Most hog wastes are discharged untreatedly into rivers and surroundings, resulting in serious environmental pollution. The pollution caused by hog wastes constitutes an important part of the total rural pollution. For example, the total amount of pollutants discharged into the Tung-Kang Stream in southern Taiwan approximates 114,446 BOD kg/day (E. P. A. [2]). Of which 86,994 BOD kg/day (76%) comes from hog wastes, causing extremely severe eutrophication of the Feng-Shan Reservoir downstream from Tung-Kang Stream.

Table 1. Statistics of pig raising in Taiwan

Scale (head)	Total farms	%	Total head	%	Ave. head
1~ 99	37,876	71.43	582,906	7.48	15
100~ 199	5,525	10.42	776,834	9.98	141
200~ 299	2,979	5.61	729,108	9.36	245
300~ 499	3,197	6.02	1,240,775	15.94	388
500~ 999	2,682	5.05	1,893,561	24.32	706
1,000~1,999	467	0.88	629,435	8.08	1,347
2,000~4,999	227	0.42	687,507	8.83	3,028
Above 5,000	69	0.13	1,243,150	15.97	18,016
Summation	53,022	100.00	7,783,276	100.00	147

Source: Council of agriculture (1990).

HOG WASTE MANAGEMENT

When wastewater is discharged into a river, floating solids may decompose and create unpleasant odors. The large amount of organic matter in the wastewater may seriously deplete the dissolved oxygen in the river resulting in harm to fish and other aquatic life or other undesirable effects. Additionally, the wastes will cause the contamination of water by pathogenic bacteria. The polluted river is a danger to the health of the community.

There are mainly two methods to treat the hog wastes, i. e., anaerobic digestion and aerobic oxidation (Tseng [7]). The former has been receiving increasing attention in Taiwan in recent years. The advantages of anaerobic fermentation of hog wastes include stabilization of organic matter, low production of waste biologic sludge, reduction of odor and production of methane gas for fuel. Since the 1960s, Taiwan has been active in generating methane gas from pig manure. The treatment of hog wastes through the Red Mud Plastic (RMP) bag digester seems practical and economical in Taiwan (Hong et al. [4]).

The most common method of wastewater disposal today is likely to be surface water discharge into rivers, lakes and oceans. The self-purification ability of receiving waters can assimilate pollutants. However, while the assimilative capacity of receiving water body is exceeded, water pollutions then result. Thus, the criteria of water quality should be available for alternative beneficial uses of water supply, recreation and ecology.

In order to protect the water resources and aquatic environment of water bodies, the Water Pollution Control Act of the Republic of China was promulgated in 1974 and revised in 1983. It is stipulated that the government should classify rivers in several categories in accordance with the beneficial uses of existing conditions. The standards for the effluent from wastewater disposal are also issued to comply with the Act. Since the regulations may be revised, depending on the economic and environmental conditions, it is anticipated that more stringent standards will be adopted in the future.

Generally, the standards enforced for effluents from wastewater disposal include requirements for pH, BOD, suspended solids (SS), nitrates, temperature, etc. The current required limitations of

Table 2. Effluent standards of hog wastes

Item\head	Above 1000	Below 1000
pH	5.0~9.0	5.0~9.0
BOD (mg/ℓ)	200	400
SS (mg/ℓ)	300	400

effluent standards for hog wastes are shown in Table 2. Those who violate the regulations will be fined NT$ 12,000 (US$ 444 approximately) at least and NT$ 60,000 (US$ 2,222 approximately) at most. It is noted that the pig raising below 200 head is free from penalty providing the effluent violates the standards.

According to the Water Pollution Control Act, the setting of effluent standards comes under the jurisdiction of the Environmental Protection Administration. There are, of course, some criteria considered applicable to the setting of standards, i. e., economic development and environmental protection. The effluent standards required will, therefore, be a compromise between what is desirable in environment and what is possible in economy. Apparently, this is a problem of multiple criteria decision making. Hence, how to reach a compromise solution between those two conflicting criteria is an art. The obvious aim is to arrive at a point which is mutually acceptable to both aspects in economy and environment. Thus, the following lays emphasis upon the policy making of effluent standards of pig raising industry by using the approach of multiple criteria decision making.

REVIEW OF THE APPLIED METHODOLOGY

The multicriterion ELECTRE is an interactive technique to handle qualitative and discrete alternatives (Tabucanon, [6]). It is a procedure to reduce the size of the set of noninferior solutions. ELECTRE is used to select alternatives which are preferred for most criteria and do not result in an unacceptable level of discontent for any criterion. Essentially, a search with ELECTRE is made within a set of noninferior alternatives based on three concepts, i. e., "concordance", "discordance" and "threshold values".

The concordance is a weighted measure of the number of criteria where alternative i is preferred to alternative j, denoted $c(i,j)$. It appears to be the satisfaction of decision maker (DM) in choosing i over j. Mathematically, the concordance index $c(i,j)$ is defined as

$$c(i,j)=\frac{\sum_{k\in S} w(k)}{\sum_k w(k)} \qquad (1)$$

where S is the union of the set of criteria for which alternative i is preferred to alternative j and that for which i is equal to j. $w(k)$ is the weight of k^{th} criterion assigned by the DM.

The discordance measures the greatest degree of discontent assuming alternative i is selected over alternative j, denoted $d(i,j)$. It appears to be the dissatisfaction of DM in choosing i over j. The discordance index is constructed through the establishment of an interval scale common to all criteria. The setup of the interval scale is like that of utility function. However, the former is much simpler and neutral attitude of the DM is assumed. Choice of a range of the interval scale between zero and one for each criterion depends upon the DM. With this understanding, the discordance index is then defined as

$$d(i,j)=\max_k \{u_k(j)-u_k(i)\} \qquad (2)$$

where alternative i is inferior to alternative j for the k^{th} criterion, and $u_k(i)$ is its evaluation similar to the value of utility function.

The threshold values within zero and one assigned by the DM specify the minimum concordance degree the DM can accept and the maximum discordance degree the DM can tolerate. That is,

$$c(i,j)\geq p \quad \text{and} \quad d(i,j)\leq q \qquad (3)$$

Suppose both requirements are met, alternative i is preferred to alternative j. Otherwise no preference order exists between i and j. With the outranking relationship of a composite graph, finally, an ordering of the alternative systems can be accomplished.

It is noted that two types, ELECTRE I and ELECTRE II arise based on the aforementioned ideas. However, the former offers a partial ordering of the noninferior alternatives, while the latter provides a complete ordering of the alternative systems. ELECTRE II is an extension of ELECTRE I. The complete ordering is carried out with the concepts of strong and weak outranking relationships and the specifications of high, average and low concordance, and high and average discordance, corresponding to the concordance threshold values (p^*, p^0, p^-) and the discordance threshold values (q^*, q^0) respectively (Tabucanon [6]). The strong outranking relationship is satisfied if

$$c(i, j)\geq p^*,\ d(i, j)\leq q^*,\ W^+(i, j)\geq W^-(i, j) \qquad (4)$$

or

$$c(i, j)\geq p^0,\ d(i, j)\leq q^0,\ W^+(i, j)\geq W^-(i, j) \qquad (5)$$

The weak outranking relationship is satisfied if

$$c(i, j)\geq p^-,\ d(i, j)\leq q^*,\ W^+(i, j)\geq W^-(i, j) \qquad (6)$$

where $W^+(i, j)$ and $W^-(i, j)$ are the sum of weights for which i is over j and i is inferior to j, respectively.

On the basis of outranking relationships, two types of graphs for strong and weak preferences are set up individually. With an iterative outranking procedure, a complete ordering of alternatives is then carried out (Goicoechea et al. [3]).

POLICY MAKING OF PIG-RAISING INDUSTRY WITH ELECTRE II

Due to the fact that the most important test of wastewater is that for biochemical oxygen demand (BOD), the setting of effluent standards of hog wastes lays stress on the polcy making of BOD in this study. Obviously, environmental protection and economic development are the essence of standard setting. It is essential that the hog wastes are treated sufficiently to safeguard the nation's water resources. However, the expense of wastewater treatment facility the pig-raising industry may be faced must be considered. Five criteria are taken into account in setting the standard herein; namely, capital cost, operating cost, water pollution, ecology, and scenery. It is noted that the criteria, capital cost and operating cost, treated with qualitative levels are acceptable with more codes. The criteria with the levels are given in Table 3, and the candidate policies are going to be evaluated with ELECTRE II.

In assigning weights of the relevant criteria, the decision makers are requested to judge the various criteria. In order to ensure that evaluations of alternatives are consistent and rational, it seems in ELECTRE that ranking approach on the basis of relative importance is more appropriate than rating approach on the basis of a predetermined scale. On the other side, in order to assess the discordance index the value of each level for each criterion has to be assigned. As mentioned above, the evaluation of $u_k(i)$ is similar to a utility function with neutral attitude of the DM. Table 4 presents the criterion weight and maximum scale intervals assigned by the DM. The value of each level for each criterion is also shown in Table 4.

1. Number of hogs above 1000 head

To meet the desired criteria, five alternatives are proposed, and the ELECTRE II is applied to evaluate the different alternatives. An assessment of the proposed alternatives is presented in Table 5 for which the number of hogs are above 1000 head per farm. Noted that the effluent standard for BOD is a maximum allowable value.

Using the assigned weights of each criterion, the concordance index can be calculated. For example, the concordance indices for alternatives A (BOD$\leq$300) and B (BOD$\leq$200) and alternatives E (BOD$\leq$80) and C (BOD$\leq$150) are:

$$c(A, B)=\frac{5+5.25+0+0+2}{20}=0.61$$

$$c(E, C)=\frac{0+5.25+4.5+3.25+2}{20}=0.75$$

The complete concordance matrix with rows i and columns j is represented as follows:

$$c(i, j)=\begin{pmatrix} - & 0.61 & 0.51^* & 0.51^* & 0.51^* \\ 0.74^* & - & 0.90^* & 0.68^* & 0.51^* \\ 0.49 & 0.49 & - & 0.78^* & 0.51 \\ 0.49 & 0.49 & 0.75 & - & 5.51 \\ 0.49 & 0.49 & 0.75^* & 0.75^* & - \end{pmatrix}$$

where only those elements of the matrix with an asterisk satisfy the condition $W^+(i, j)\geq W^-(i, j)$.

Once the numerical values for the criterion levels have been assigned, the discordance index

Table 3. Levels of criteria

Criteria\levels\code	1	2	3	4
Capital cost	very costly	costly	medium	low
Operating cost	very costly	costly	medium	low
Water pollution	very serious	serious	medium	low
Ecology	very bad	bed	acceptable	—
Scenery	unacceptable	acceptable	good	—

Table 4. Relative ranking of criteria

Criteria	Weights	Max. u_k	Scale interval
Capital cost	5.00	1.00	0.25
Operating cost	5.25	1.00	0.25
Water pollution	4.50	0.80	0.20
Ecology	3.25	0.75	0.25
Scenery	2.00	0.60	0.20

Table 5. Evaluation of alternatives

Criteria\code\BOD	300 mg/ℓ	200 mg/ℓ	150 mg/ℓ	100 mg/ℓ	80 mg/ℓ
Capital cost	4	4	3	2	1
Operating cost	4	3	2	2	2
Water pollution	1	2	2	3	4
Ecology	1	2	2	2	3
Scenery	1	1	2	2	3

can be evaluated. The discordance index calculation for alternatives E and A is illustrated as follows:

$d(E, A)$: capital cost $=1.0-0.25=0.75$

$d(E, A)$: operating cost $=1.0-0.5=0.5$

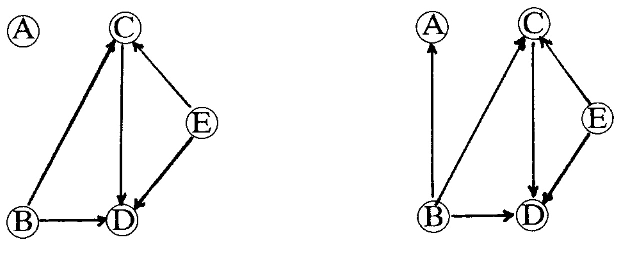
$d(E, A)$: $max\, d(E, A)=0.75$

The complete set of indices with rows i and columns j is represented by the following discordance matrix:

$$d(i, j)=\begin{pmatrix} - & 0.25 & 0.25 & 0.40 & 0.60 \\ 0.25 & - & 0.20 & 0.20 & 0.40 \\ 0.50 & 0.25 & - & 0.20 & 0.40 \\ 0.50 & 0.50 & 0.25 & - & 0.25 \\ 0.75 & 0.75 & 0.50 & 0.25 & - \end{pmatrix}$$

Through the use of the concordance and discordance matrices, strong and weak outranking relationships can be then found with the specification of threshold values by the DM. Suppose that the concordance threshold values (p^*, p^0, p^-) and discordance threshold values (q^*, q^0) are (0.75, 0.65, 0.6) and (0.65, 0.2) respectively, the strong and weak composite graphs can be constructed based on the requirements of Eqs. (4)~(6). The two graphs are shown in Fig. 1. It can be seen that alternative D is dominated by alternatives B, C and E. Alternatives A and B do not dominate each other in strong relationship, whereas alternative B dominates alternative A in weak relationship. The ranking procedure consists of forward ranking and reverse ranking. With an iterative procedure, the forward ranking and reverse ranking can be obtained consequently (see Table 6). Take an average ranking as the final complete ordering of alternatives. It was found that alternative B (BOD≤200) and alternative E (BOD≤80) perform best.

To find out how sensitive the above solution is to the choices of threshold values, a sensitivity analysis by changing the threshold values and noting the effect on the current solution can be done. From the sensitivity analysis as can be seen from Table 7, alternative B (BOD≤200) appears to be most preferable among these five proposed alternatives. As compared with current policy (see Table 2), alternative B the final choice through ELECTRE technique is consistent with current policy. It can be concluded that the current effluent standard of BOD at most 200 mg/ℓ for pigs above 1000 head/farm should be reasonable and acceptable.



(a) Strong (b) Weak

Fig. 1. Strong and weak relationships for pigs above 1000 head.

2. Number of hogs below 1000 head

Following the similar procedure as above, the effluent standard of BOD for pigs below 1000 head per farm can be determined. Originally, six alternatives are proposed. The performance of these alternatives is given in Table 8. Though alternative BOD≤500 is similar to alternative BOD≤400, it seems the latter one is preferred by the DM. Furthermore, alternative BOD≤80 is dominated by alternative BOD≤100. Consequently, alternatives BOD≤500 and BOD≤80 are eliminated here.

Table 6. Relative ranking of alternatives

Alternative	A	B	C	D	E
Forward ranking	2	1	2	3	1
Reverse ranking	3	1	2	3	1
Average ranking	2.5	1	2	3	1

Table 7. Sensitivity analysis of relative ranking

(p^*, p^0, p^-), (q^*, q^0)\alternative	A	B	C	D	E
(0.75, 0.65, 0.6), (0.65, 0.2)	2.5	1	2	3	1
(0.70, 0.60, 0.5), (0.65, 0.2)	2	1	4	5	3
(0.80, 0.70, 0.6), (0.65, 0.25)	2.5	1	2	3	1
(0.70, 0.60, 0.5), (0.40, 0.2)	2	1	3	4	2.5

Table 8. Evaluation of alternatives

Criteria\code\BOD	500 mg/ℓ	400 mg/ℓ	300 mg/ℓ	200 mg/ℓ	100 mg/ℓ	80 mg/ℓ
Capital cost	4	4	3	2	1	1
Operating cost	4	4	3	2	2	1
Water pollution	1	1	2	3	4	4
Ecology	1	1	2	2	3	3
Scenery	1	1	2	2	3	3

Similarly, the complete set of indices of concordance matrix and discordance matrix without the consideration of alternatives BOD≤500 and BOD≤80 are respectively given as follows:

$$c(i,j)=\begin{pmatrix} - & 0.51^* & 0.51^* & 0.51^* \\ 0.49 & - & 0.78^* & 0.51^* \\ 0.49 & 0.49 & - & 0.51 \\ 0.49 & 0.49 & 0.75^* & - \end{pmatrix}$$

$$d(i,j)=\begin{pmatrix} - & 0.25 & 0.40 & 0.60 \\ 0.25 & - & 0.20 & 0.40 \\ 0.50 & 0.25 & - & 0.25 \\ 0.75 & 0.50 & 0.25 & - \end{pmatrix}$$

By using the concordance and discordance matrices, strong and weak outranking relationships can be also built up with the desired threshold values. With (p^*, p^0, p^-) and (q^*, q^0) corresponding to (0.70, 0.60, 0.5) and (0.65, 0.2), the strong and weak outranking graphs are shown in Fig. 2, for example. It indicates that alternative C (BOD≤200) is dominated by alternatives B (BOD≤300) and alternative D (BOD≤100) within both strong and weak relationships. Alternatives A (BOD≤400) and B do not dominate each other in strong relationship, whereas alternative B is dominated by alternative A in weak relationship. Accordingly, the average ranking shows that alternative A (BOD≤400) is best (see Table 9). Take notice that alternative A is consistent with the current policy.

Nevertheless, as a result of the sensitivity analysis shown in Table 9, alternative B (BOD≤300) seems to be acceptable among these four proposed alternatives. That is, the current policy of effluent standard for pigs below 1000 head may be modified and restricted to BOD≤300 mg/ℓ in certain surroundings. Due to the fact that different alternatives may obtain same ranking in ELECTRE, the solutions can be inspected again by a sensitivity analysis or by other multicriterion techniques, if necessary.

(a) Strong (b) Weak

Fig. 2. Strong and weak relationships for pigs below 1000 head.

Table 9. Sensitivity analysis of relative ranking

(p^*, p^0, p^-), (q^*, q^0)\alternative	A	B	C	D
(0.75, 0.65, 0.6), (0.65, 0.2)	1.5	1	2	1
(0.70, 0.60, 0.5), (0.65, 0.2)	1	2	4	3
(0.80, 0.70, 0.6), (0.65, 0.25)	1.5	1	2	1
(0.70, 0.60, 0.5), (0.40, 0.2)	1	2	4	3

CONCLUSION

The policy making of effluent standard related to the pig-raising industry in Taiwan is presented by using the multicriterion algorithm ELECTRE II. In this paper, the application of ELECTRE method to handle nonquantifiable criteria and discrete alternatives appears efficient. It can be reasonably concluded that the current effluent standard of BOD for hog wastes is appropriate in Taiwan. Since the effluent standard is that for common water bodies, local authorities can specify more stringent standards for some specific protected water bodies.

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