

STRUCTURE ANALYSIS OF ISSUES REGARDING THE SUCCESSOR SHORTAGE IN FISHERY COMMUNITIES AND ITS COUNTERMEASURES (EXAMPLE ANALYSIS OF TOMAMAE TOWN, HOKKAIDO, JAPAN)

Atsumi FURUYA, Marine Planning Inc , atsumi.f@cello.ocn.ne.jp
Izumi SEKI, Sadayuki OKA ,Akira NAGANO

ABSTRACT

This paper gives an attribution analysis of successor decrease in fishery communities using DEMATEL (Decision-Making Trial and Evaluation Laboratory)

Keywords: Problem of successors of in fisheries ,DEMATEL method, ISM

INTRODUCTION

This study addresses the factors that are causing a shortage of successors in fishery and possible countermeasures. The interrelating structure of these factors was clarified using the DEMATEL (DEcision MAKing Trial and Evaluation Laboratory) method and the effectiveness of the countermeasures was evaluated. Problem-causing factors were also hierarchized using ISM (Interpretive Structural Modeling).

Furthermore, validity of these methods for analyzing the issue of lack of successors was studied through a comparison of the interrelating structure of the factors found by the DEMATEL method and the hierarchical structure found by ISM.

Factors causing problems of successors in fishery were divided into three categories – industry, living & culture and self-actualization – and the interaction among the factors was analyzed using the DEMATEL method. Next, as a paired comparison with the DEMATEL method, problem-causing factors were hierarchized by ISM, using the direct influence matrix developed from the results of the DEMATEL method analysis. Countermeasures for the factors causing the shortage of successors in fishery were then extracted, and the effectiveness of those countermeasures was evaluated from the viewpoint of comprehensive problem-solving effects taking into consideration the total influence coefficient obtained by the DEMATEL method.

The problem structure and effectiveness of countermeasures clarified by the above methods were fed back to the subjects for adjusted evaluation.

FACTORS CAUSING A LACK OF SUCCESSORS IN FISHERY AND POSSIBLE COUNTERMEASURES

Tomamae Town on the Sea of Japan coast was chosen as the target area for the study, because the decline of fishery is especially significant in this area of Hokkaido and the entire coast is facing the problem of lack of successors.

Factors contributing to a lack of successors in Tomamae Town and possible countermeasures were determined from a preliminary survey and existing data (Table II).

Table I: Subjects in Tomamae Town

Classification	No. of people	Sex
Fishery-related people	2	Female 2
Education-related people	1	Male 1
Town development-related people	1	Female 1
Government-related people	2	Male 2
Total	6	Male/female 3 each

Table II: Factors and countermeasures

	Factors	Countermeasures
Promotion of industry (fishery)	<ul style="list-style-type: none"> • Requirement of capital investment, personnel expenses and other fishery expenses • Impossibility of year-round operation and no prospect of year-round income • Slump in fish prices • Distribution system led by brokers • Shortage of side-job opportunities • Lack of places for direct sales and promotion of marine products 	<ul style="list-style-type: none"> • Promotion of cooperative operation • Promotion of aquaculture • Value-added service • Consolidation of the functions of the fishermen's cooperative • Industrial promotion in the region in cooperation with the fishing industry • Promotion and direct sales of marine products at morning markets and existing facilities
Promotion of living & culture	<ul style="list-style-type: none"> • Long working hours without holidays in the peak fishing season • Biased facility distribution in the region and inconvenience of living due to the underdeveloped regional traffic system • Lack of education for children on regional industries, history, etc. • Lack of system for payment of wages to successors within management bodies 	<ul style="list-style-type: none"> • Establishment of uniform holidays for the entire region • Promotion of town development taking the convenience of living into account • Implementation of education on regional industries, history, etc. • Making arrangements concerning wages through family agreements, etc.
Self-actualization	<ul style="list-style-type: none"> • Lack of exchange with people in other regions • Difficulty in realization of ideas and plans proposed by fishermen themselves • Lack of opportunities and places for education and self-enlightenment 	<ul style="list-style-type: none"> • Implementation of first-hand fishery experience and other exchange projects to make the most of regional characteristics • Provision of support and funds by the town government for realization of new projects and plans • Community understanding of self-actualization and provision of public subsidies

As shown in Table I, a paired comparison was made by inquiring about the influences of and on individual factors upon six subjects consisting primarily of fishery-related persons. Next, the effectiveness of countermeasures considered useful for addressing these factors (comprehensive problem-solving effect) was studied.

Details of the selection and number of subjects are presented by Kodama et al. When analyzing interaction among regional factors using the DEMATEL and other methods, however, the number of subjects has almost no effect on the outcome, as long as the subjects have comprehensive knowledge of the target area's industry and life & culture. Since it is also necessary to repeat discussions based on the

analysis method in the process of specifying factors and countermeasures, six subjects who were well-informed of regional issues were selected.

ANALYSIS METHOD AND RESULTS

Seriousness of the factors by direct evaluation

Table III shows the results of direct evaluation of seriousness of the factors causing the shortage of successors.

Of the 13 factors, those concerning expenses and income of fishing households, such as nos. 1 and 3, scored high and were regarded as most serious.

Many people considered factors 8 and 9 as not serious.

Table III: Evaluation of seriousness of the factors

No.	Factors in Tomamae Town	Score
1	Requirement of capital investment, personnel expenses and other fishery expenses	28
2	Impossibility of year-round operation and no prospect of year-round income	23
3	Slump in fish prices	25
4	Distribution system led by brokers	22
5	Shortage of side-job opportunities	17
6	Lack of places for direct sales and promotion of marine products	25
7	Long working hours without holidays in the peak fishing season	21
8	Biased facility distribution in the region and inconvenience of living due to the underdeveloped regional traffic system	12
9	Lack of education for children about regional industries, history, etc.	14
10	Lack of system for payment of wages to successors within management bodies	21
11	Lack of exchange with people in other regions	16
12	Difficulty in realization of ideas and plans proposed by fishermen themselves	18
13	Lack of opportunities and places for education and self-enlightenment	17

※In the survey, the level of seriousness (5 = most serious, 1 = least serious) for each factor was found and multiplied by 5, 4, 3, 2 or 1 depending on its level.

Interaction among problem-causing factors and indexes of factors

DEMATEL is a method used for finding the total influence matrix, including indirect influences among factors, by finding the direct influence matrix among factors from the paired comparison survey of influences of and on problem-causing factors and calculating its inverse matrix.

$$T = X(I - X)^{-1} \quad (\text{Eq. 1})$$

T: total influence matrix
X: direct influence matrix
I: unit matrix

The sum of the rows of the comprehensive influence matrix expresses the degree of influence of the row factor on the interaction among factors. The total sequence expresses the degree of influence on the factors of the sequence. The total of influences on and of the factors expresses the central position of the

factor in the total influence matrix. The difference between the influences on and of the factors indicates the causal position of the factor in the total influence matrix.

Table IV illustrates the degrees of influences on and of factors, the causality and the centrality.

Table IV: Characteristic values of total influence

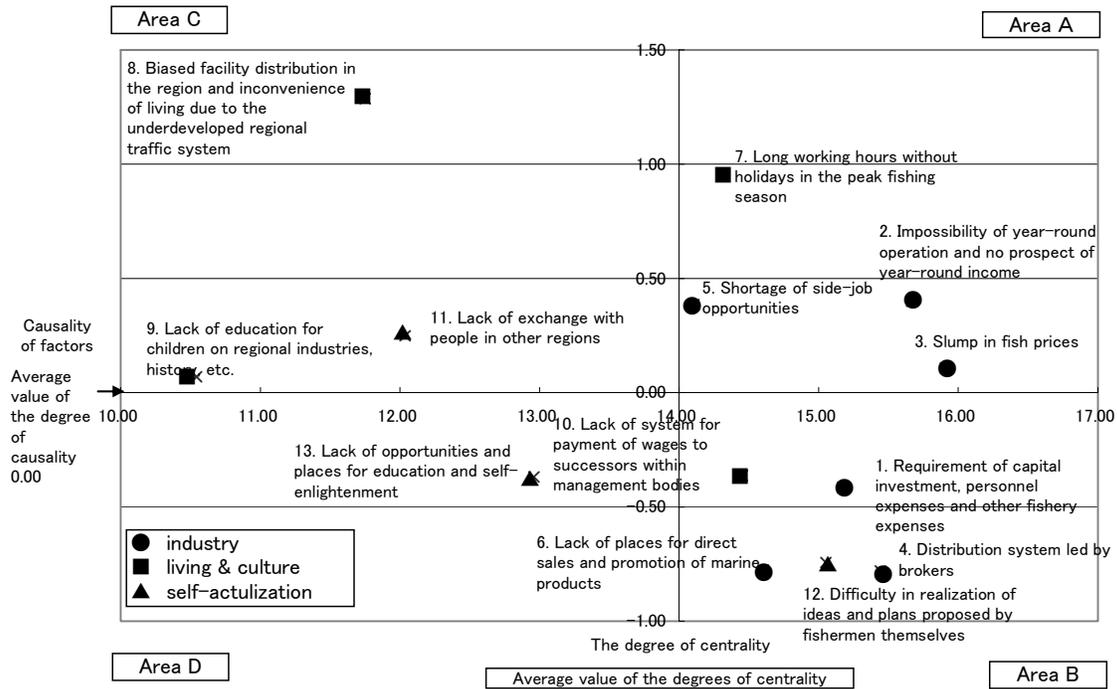
	The degrees of influences on factors (sum of the rows)	The degrees of influences of factors (The total sequence)	The degrees of the causality	The degrees of the centrality	Ranking with the large degree of the centrality
1. Requirement of capital investment, personnel expenses and other fishery expenses	7.38	7.79	-0.42	15.17	4
2. Impossibility of year-round operation and no prospect of year-round income	8.03	7.63	0.40	15.67	2
3. Slump in fish prices	8.01	7.90	0.11	15.91	1
4. Distribution system led by brokers	7.33	8.11	-0.78	15.44	3
5. Shortage of side-job opportunities	7.25	6.86	0.39	14.11	9
6. Lack of places for direct sales and promotion of marine products	6.91	7.69	-0.78	14.60	6
7. Long working hours without holidays in the peak fishing season	7.63	6.68	0.95	14.31	8
8. Biased facility distribution in the region and inconvenience of living due to the underdeveloped regional traffic system	6.52	5.23	1.29	11.75	12
9. Lack of education for children on regional industries, history, etc.	5.31	5.24	0.07	10.54	13
10. Lack of system for payment of wages to successors within management bodies	7.05	7.41	-0.36	14.45	7
11. Lack of exchange with people in other regions	6.14	5.89	0.25	12.04	11
12. Difficulty in realization of ideas and plans proposed by fishermen themselves	7.15	7.90	-0.74	15.05	5
13. Lack of opportunities and places for education and self-enlightenment	6.30	6.66	-0.37	12.96	10

※The degree of influence on and of factors, the degrees of the centrality surrounded five higher ranks by the double line, the degrees of the causality surrounded three higher ranks by the double line, and surrounded three low ranks by thick line.

Table IV demonstrates that the problem-causing factors related to the development of industry, such as factors 3, 2 and 4, are central factors with a high degree of centrality. Factors related to promotion of living & culture, such as nos. 8 and 7, are causal factors with a high degree of causality.

Next, Figure 1 shows the relationship between the degree of centrality and causality, as well as the classification of factors.

In Figure 1, factors positioned in Area A are central factors that also have an influence on other factors. Those positioned in Area B are central factors but do not affect other factors. The degree of centrality is high for factors related to the promotion of the industry. Factors positioned in Areas C and D are related to the promotion of living & culture and self-actualization, and are recognized as causal factors although they are not central.



- ※ Area A: The degree of causality larger than 0, the degree of centrality above the average value (14.00).
- Area B: The degree of causality smaller than 0, the degree of centrality above average value.
- Area C: The degree of causality larger than 0, the degree of centrality by under average value.
- Area D: The degree of causality smaller than 0, the degree of centrality by under average value.

Figure 1. Relationship between the degree of centrality and causality of factors

The degree of centrality of factors and degree of seriousness in direct evaluation

Figure 2 presents the results of standardizing and plotting the degree of seriousness of the factors shown in Table III and the degree of centrality given in Table IV (straight lines in the figures are lines with a gradient of 1).

Here, if there is no indirect influence among factors, the degree of centrality and degree of seriousness in direct evaluation are equal and plotted points are positioned on a straight line.

According to Figure 2, the degree of direct seriousness that does not include indirect influences is high for factors 1 and 6, which are deviating downward from the straight line, while the degree of seriousness including indirect influences is high for 5 and 12, which are deviating upward.

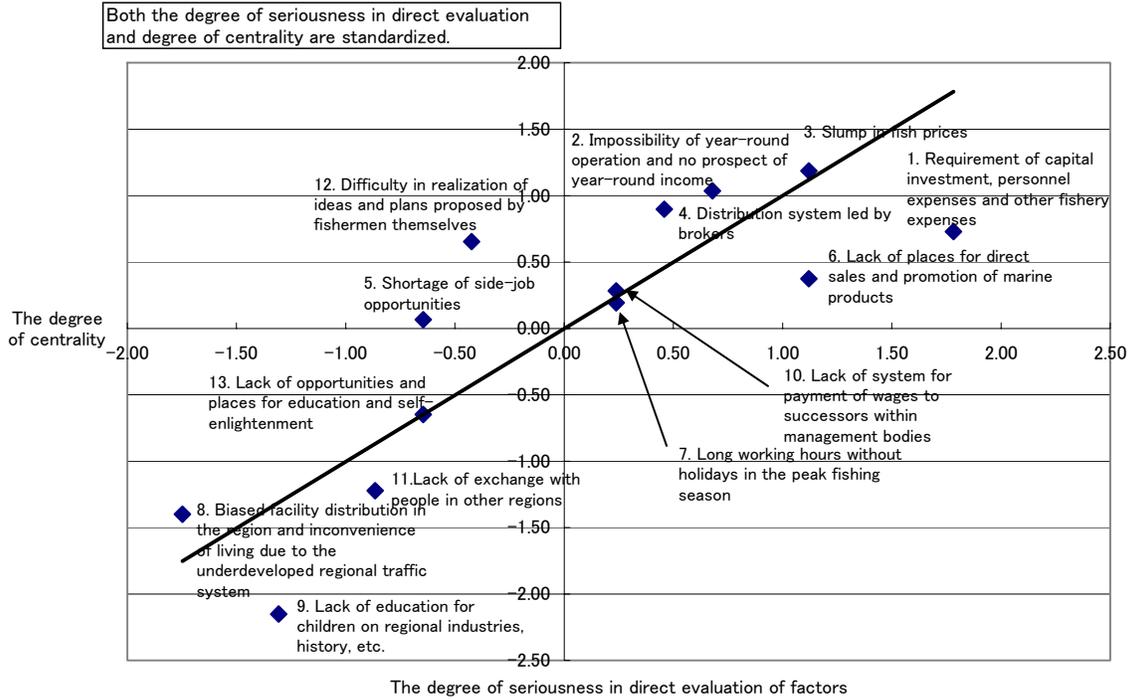


Figure 2. Relationship between the degree of centrality and degree of seriousness in direct evaluation of factors

Hierarchization of problem-causing factors from the cause to the outcome

ISM is a method used for representing a number of factors constituting a problem as a hierarchical structure model. Here, the direct influence matrix found by the DEMATEL method was used in analysis of ISM. From this direct influence matrix, the direct influence matrix of 1 and 0 (adjacency matrix: A) was created by substituting 1 for factors of a certain value or higher and 0 for those lower than that. The attainable matrix (T_A) was found by repeating the calculation according to the algorithm of Boolean algebra until the matrix, which was the total of this adjacency matrix (A) and unit matrix I, would satisfy Equation 2.

$$(A+I)^{r-1}=(A+I)^r=(A+I)^{r+1}=T_A \quad (\text{Eq. 2})$$

T_A : attainable matrix, A: adjacency matrix, I: unit matrix

Conversion from the direct influence matrix to adjacency matrix was performed in the following manner: The existence of influences among factors was determined by substituting 1 for those with direct influence coefficients of the top quartile or higher as factors with influences and 0 for those with lower coefficients as unrelated factors. Transitive law was then applied in a paired comparison, and an adjacency matrix was created by determining 1 and 0 again through screening of diagonal elements. In transitive law, 1 was substituted for that with a larger direct influence coefficient, because it is impossible for two factors to influence each other when viewing Factor b from Factor a or Factor a from Factor b.

Although hierarchization of causes was possible, multiple factors were positioned on the same level. To hierarchize the causes among these multiple factors, hierarchization of causes of factors on the same level

was conducted after creating an adjacency matrix in the same manner as the attainable matrix was found from the direct influence matrix of multiple factors on the same level.

Although hierarchization of factors is performed using the above process, two or three hierarchies consisting of multiple factors are often divided from independent factors in actual cases. In such a hierarchical structure with a small number of factors, the structure from the cause to outcome of factors cannot be clarified. A new adjacency matrix of multiple factors divided into two or three hierarchies was therefore created to find the attainable matrix from the divided adjacency matrix, and hierarchization was conducted among divided factors. Since the direct influence matrix and adjacency matrix are obtained by a paired comparison among factors, elimination of certain factors from the matrix will not affect other factors. It is therefore possible to conduct such a process.

Figure 3 indicates hierarchization of factors using the above calculation.

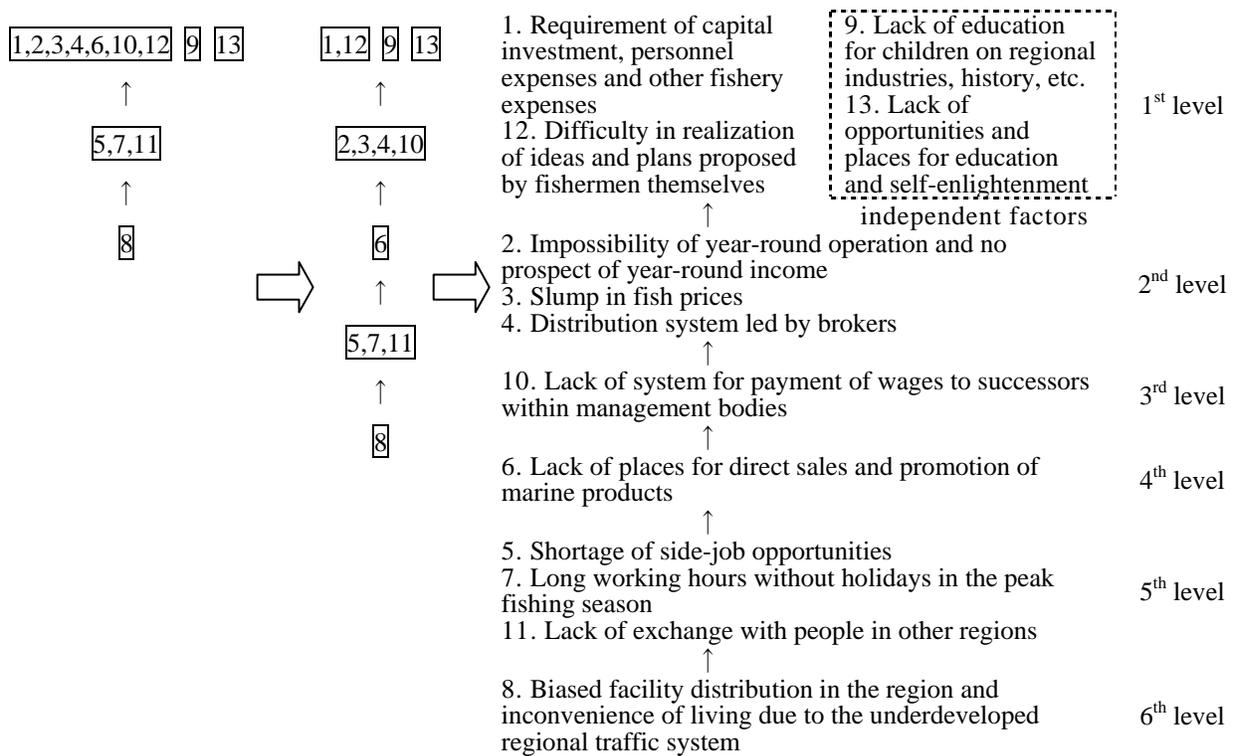


Figure 3. Hierarchy diagram of factors causing shortage of successors

It can be seen from the factor hierarchy diagram in Figure 3 that factors positioned in the low 5th and 6th level, such as nos. 5 and 8, were causal factors that affect all factors contributing to the shortage of successors.

It can also be seen that factors 9 and 13 existed independently and were not caused or influenced by others in the hierarchy diagram.

Relationship between the interaction among problem-causing factors and hierarchy of factors

It is presumed that the interaction among problem-causing factors and the centrality, causality and other indexes calculated using the DEMATEL method and hierarchy of factors determined using ISM are related to each other because they were calculated based on the same direct influence matrix. If the relationship between the problem structure analysis of the DEMATEL method and hierarchy of factors of ISM can be clarified, the structure of problems of successors in fishery can be understood more accurately.

The causality and centrality of problem-causing factors by the DEMATEL method were plotted, and, together with the hierarchy of ISM, are shown in Figure 4.

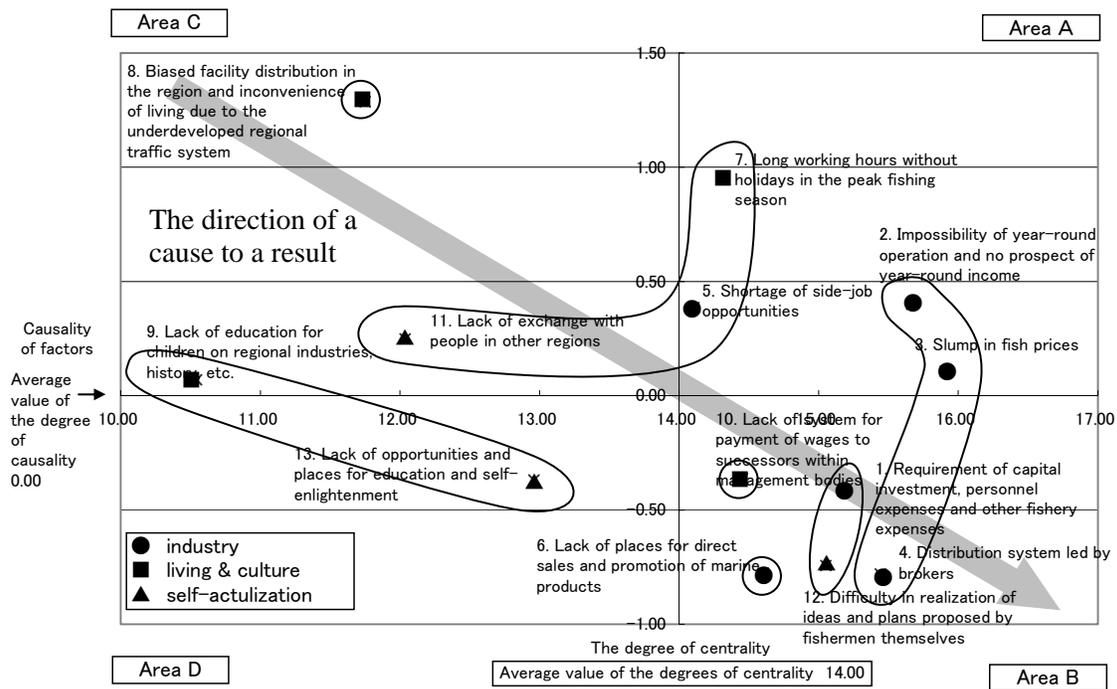


Figure 4. Degrees of causality and centrality by the DEMATEL method and hierarchy by ISM

It can be seen from Figure 4 that the problem-causing factors in the lower levels (5th and 6th levels), which are supposed to be causal factors in ISM analysis, are mostly factors related to living & culture and self-actualization and can be regarded as factors that affect others because of their high causality.

While many problem-causing factors on the upper levels (1st, 2nd and 3rd levels) are industry-related, they are affected by other factors and have a high degree of centrality.

In other words, the following matters were clarified from both the results of ISM and the DEMATEL method: ① problem-causing factors related to living & culture and self-actualization are causal factors, while industry-related factors are central factors affected by other factors and ② the results of the two methods of analysis are related to each other.

The following relationships were clarified as a result of a comparison between the degree of causality and centrality in the results of the DEMATEL method analysis and the hierarchy by ISM: ① causal factors in ISM are causal factors in the problem structure and ② factors affected in ISM are central factors in the problem structure.

METHOD FOR EVALUATION OF EFFECTIVENESS OF COUNTERMEASURES

The effectiveness of countermeasures was evaluated in the following manner:

As a result of the survey of five hierarchical scores concerning the effectiveness of countermeasures displayed in Table II for resolution of problem-causing factors, the evaluation score matrix (H) can be found as shown in Table V. It is a direct evaluation of effectiveness for each problem-causing factor of each countermeasure. It is also necessary to take indirect influences into account when evaluating the effectiveness of countermeasures because problem-causing factors are related to each other.

Influences including indirect influences among factors were calculated for each problem-causing factor shown in Table IV and were expressed as the total influence vector (E) composed of those influences. Equation 3, which is the product of the mean evaluation score matrix (V) multiplied by the total influence vector (E), becomes the total problem-solving effect vector (B) formed by evaluation of effectiveness of each countermeasure (bi).

The process of analysis of the total problem-solving effect is as follows:

The total influence vector (E), which is the total of factors of each sequence, is found from the total influence matrix (T) found using the DEMATEL method.

Six subjects score the effectiveness of countermeasures shown on the sequence for solution of problems described on the row, and the mean evaluation score and mean evaluation score matrix (V) of their responses are found.

The total problem-solving effect vector (B) of each countermeasure can be found by multiplying the mean evaluation score matrix (V) by the total influence vector (E) from the right.

$$V \times E = B \quad (\text{Eq. 3})$$

V: mean evaluation score matrix

E: total influence vector

B: total problem-solving effect vector

Table V shows the total problem-solving effect of each countermeasure for Tomamae Town. Countermeasures 1, 2, 3 and 4 with high total problem-solving effect vectors are thought to have high problem-solving efficacy. It can be seen that countermeasures related to cost reduction and new distribution procedures are regarded as effective for Tomamae Town.

Table V: Calculation of mean evaluation score matrix (V) and total problem-solving effect vector

	1. Requirement of capital investment, personnel expenses and other fishery expenses	2. Impossibility of year-round operation and no prospect of year-round income	3. Slump in fish prices	4. Distribution system led by brokers	5. Shortage of side-job opportunities	6. Lack of places for direct sales and promotion of marine products	7. Long working hours without holidays in the peak fishing season	8. Biased facility distribution in the region and inconvenience of living due to the undeveloped regional traffic system	9. Lack of education for children on regional industries, history, etc.	10. Lack of system for payment of wages to successors within management bodies	11. Lack of exchange with people in other regions	12. Difficulty in realization of ideas and plans proposed by fishermen themselves	13. Lack of opportunities and self-enlightenment	Total influence vector (E)	Total problem-solving effect vector (B)	Evaluation score matrix (H)
1. Promotion of cooperative operation	2.3	2.2	2.3	1.8	2.3	2.3	2.3	1.5	1.2	2.3	2.2	2.2	7.38	193.64	25	
2. Promotion of aquaculture	2.2	2.5	2.0	2.2	2.0	1.7	1.7	1.3	1.2	2.3	1.3	2.2	8.03	176.4	28	
3. Value-added service	2.3	2.2	2.5	2.0	1.7	2.5	1.5	1.3	1.5	1.5	1.7	2.2	8.01	172.51	22	
4. Consolidation of the functions of the fishermen's cooperative	1.5	2.0	2.7	2.5	1.8	2.3	1.3	1.8	1.3	2.0	1.5	2.3	7.33	175.92	26	
5. Industrial promotion in the region in cooperation with the fishing industry	1.5	2.3	2.3	1.7	1.7	2.7	1.3	1.7	1.3	1.5	1.8	2.0	7.25	167.02	24	
6. Promotion and direct sales of marine products at morning markets and existing facilities	1.5	2.2	2.5	2.0	1.7	3.0	1.2	1.7	1.0	1.5	1.8	1.8	6.91	166.48	23	
7. Establishment of uniform holidays for the entire region	1.7	1.7	2.0	2.0	1.3	1.2	2.3	1.2	1.2	1.5	2.0	1.7	7.63	149.91	19	
8. Promotion of town development taking the convenience of living into account	0.8	1.0	1.5	1.0	1.5	2.3	1.2	2.2	1.2	1.0	1.3	1.8	6.52	126.49	23	
9. Implementation of education on regional industries, history, etc.	1.0	1.2	1.3	1.3	1.3	1.3	0.8	1.3	2.0	1.3	1.3	1.3	5.31	121.46	18	
10. Making arrangements concerning wages through family agreements, etc.	1.0	2.0	1.2	1.3	1.3	1.3	1.5	1.0	0.8	2.2	1.0	1.2	7.05	121.97	22	
11. Implementation of first-hand fishery experience and other exchange projects to make the most of regional	1.2	1.3	1.0	1.2	1.3	2.0	1.0	1.3	1.3	1.2	2.2	1.7	6.14	127.76	20	
12. Provision of support and funds by the town government for realization of new projects and plans	2.2	2.0	1.7	1.5	1.8	2.7	1.5	1.3	1.3	1.5	1.8	2.5	7.15	165.53	23	
13. Community understanding of self-actualization and provision of public subsidies	2.2	1.8	1.5	1.2	1.5	2.3	1.3	1.5	1.2	1.5	1.8	2.3	6.30	154.48	24	

Figure 5 depicts the results of standardization and plotting of the total problem-solving effect and direct evaluation scores shown in Table V.

The total problem-solving effect should be the same as the direct evaluation score (H) of each countermeasure, if there is no indirect effect among problem-causing factors and the effectiveness of each countermeasure for each problem is not evaluated.

In Tomamae Town, countermeasures deviating downward from the straight line in Figure 5 are those related to living & culture, and those deviating upward are mainly related to fishery. This means that countermeasures related to living & culture are considered to have significant direct effect, while the problem-solving effect of fishery-related countermeasures is high, including direct and indirect ripple effects.

From the above, it can be seen that people of Tomamae tend to seek out countermeasures to improve the living environment with direct effects, due to the location of the town.

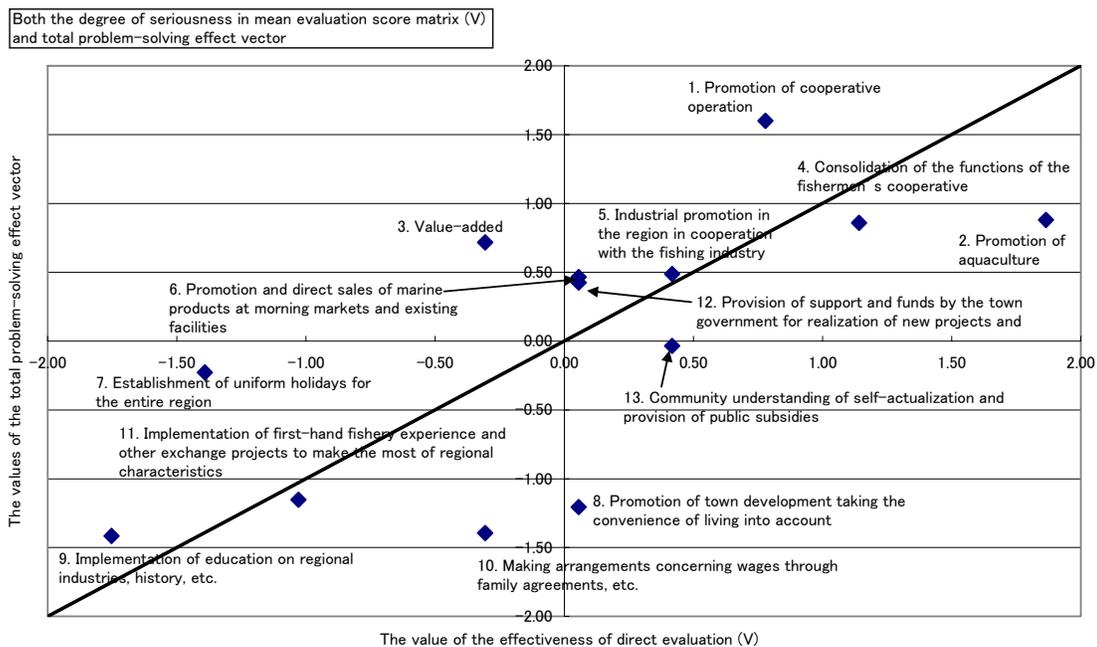


Figure 5. Comparison of the values of the total problem-solving effect vector and effectiveness of direct evaluation

FEEDBACK OF THE RESULTS TO SUBJECTS AND ADJUSTED EVALUATION

The opinions of the six subjects were heard concerning the problem structure and effectiveness of countermeasures, which were clarified through analyses by different methods, and comprehensive evaluation was conducted reflecting their opinions.

Primary factors causing the shortage of successors in Tomamae Town are those related directly to fishery, and correspond with the opinion of the subjects that the mass-catch and low-price systems based on the

decrease in resources and slump in fish prices are causing economic problems. In addition, the subjects stated that long working hours, also identified in the analysis results as a factor contributing to the shortage of successors, was a serious problem for young people and women.

In the analysis results, economic and distribution-related factors were considered to have serious direct influences while the lack of opportunities for side jobs or difficulty in actualization of ideas and plans were regarded as potentially serious factors including indirect influences. It was, however, pointed out that analysis by type of fishery should also be made because it is difficult for coastal fishing households in this region to have side jobs and evaluation of factors causing the shortage of successors also varies by type of fishery.

Concerning countermeasures, it is difficult to obtain consensus among local people on cooperative operation under the actual circumstances, although the effectiveness of cooperative operation and value-added service was high in the analysis results.

The subjects also expressed the opinion that, while regional countermeasures are important, it is necessary to undertake administrative measures simultaneously, such as funding and deregulation, in order to solve the problems.

MAIN CONCLUSIONS AND FUTURE TASKS

As a result of analysis of interaction among factors using the DEMATEL method, it was found that the central factors causing the shortage of successors are those related to the fishery characteristics of the Sea of Japan where year-round operation is impossible, as well as a result of the slump in fish prices. In the causal structure analysis using ISM, factors particular to rural fishing areas, such as inconvenience of community living, shortage of opportunities for side jobs and lack of exchange with other regions, were found to be causal factors (Figure 1 and 3).

Interaction among problems, centrality and causality can all be found by the DEMATEL method and, with limited problem-causing factors, such factors can be hierarchized by ISM (Figure 4). Causal factors at the lower levels in ISM are causal problems in the problem structure found by the DEMATEL method, and many of them are related to living & culture or self-actualization. Factors affected by others in ISM are central factors in the problem structure, and many of them are related to fishery.

In the evaluation of effectiveness of countermeasures, direct effectiveness of countermeasures related to living & culture is significant. Total problem-solving effect including indirect ripple effects is high for fishery-related countermeasures.

By feeding back the analysis results of different methods to the subjects and making adjustments, it is possible to accurately understand the issues and take appropriate countermeasures to solve regional problems.

Results of ISM may vary by threshold when determining 1 and 0 in the direct effect matrix in the ISM analysis. It will therefore be necessary to further evaluate the analysis results of ISM by conducting ISM by setting multiple thresholds and taking the opinions of subjects concerning interaction and outcome of factors into account in the future.