Regular paper

Stochastic DEMATEL for structural modeling of a complex problematique for realizing safe, secure and reliable society

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Abstract— In this paper we propose a revised Decision Making Trial and Evaluation Laboratory (DEMATEL), called stochastic DEMATEL, to extract structural model of a complex problematique and to represent the priority of each factor taking into account the uncertainty of structure. In the stochastic DEMATEL, the uncertainty of structure is expressed as a stochastic model. From numerical experiments and experimental analyses, the following results are obtained: when the structure is uncertain, stochastic DEMATEL could extract the features of structure by the degree of dispatching influences and the degree of central role; stochastic composite importance could express the uncertainty of priority and decide the priority taking into account the attitude of the decision maker; pessimistic, neutral or optimistic.

Keywords— safe, secure and reliable society, structural modeling, stochastic DEMATEL, stochastic composite importance.

1. Introduction

Decision Making Traial and Evaluation Laboratory (DEMATEL) has been widely used to extract a problem structure of a complex problematique [1–3]. By using DEMATEL we could quantitatively extract interrelationship among multiple factors contained in the problematique. In this case not only the direct influences but also the indirect influences among multiple factors are taken into account. Furthermore, we could find the dispatching factors that will rather affect the other factors, the receiving factors that will be rather affected by the other factors, the central factors that the intensity of sum of dispatching and receiving influences is big, and so forth.

It is important and useful to get the structural model of a problematique from which we could find the priority among multiple strategies to improve the structure. This is the main aim of DEMATEL. However, the conventional DEMATEL is insufficient to obtain significant implication of the priority of the strategies for decision making as follows:

1. Shortage of information on the importance of each factor

   Suppose we got three factors; "to get enough income", "to get successor", "to improve productivity", in the problematique of agriculture. The decision maker is trying to find the order of priority among these three factors. Suppose the conventional DEMATEL found that "to improve productivity" is the most influential factor to improve the problem structure. However, if "to get successor" is the most important factor in the future agricultural problem, this factor should be the first priority for the strategic planning of agriculture. In the conventional DEMATEL it is hard to find the superiority of factors, since we could get only interrelationship of factors contained in the problematique. To overcome this difficulty we proposed a new criterion "composite importance (CI)" [4] combining the interrelationship of factors and the importance of each factor.

2. Shortage of flexibility to describe structural uncertainty

   Conventional DEMATEL describes the deterministic interrelationship among factors contained in the problematique. However, the strength of the interrelation among factors may be dependent on the various situations, and the fluctuation may depend on the factors taken into account. For example, in the agricultural problematique, "to improve productivity" may contribute "to get enough income", but to what extent may be dependent on each farmhouse. "To get enough income" may contribute "to get successor" uniformly.

In this paper in the context of finding priority among multiple strategies to improve the structure of the problematique, we aim at three objectives as follows:

- We propose a stochastic DEMATEL to deal with flexible interrelationship among factors in the problematique.
- We show usefulness and future problem of stochastic DEMATEL through an empirical analysis of a simple numerical example where we deal with structural modeling of uneasy factors of university students and unmarried adults.
- We try to extract effective strategies to realize safe, secure and reliable society as the results of empirical analysis of uneasy factors of university students and unmarried adults.

2. DEMATEL and composite importance

2.1. Outline of DEMATEL

Suppose, in a complex problematique composed of n factors, binary relations and the strength of each relation are investigated. An example of binary relation is such that "How much would it contribute to resolve factor j by resolving factor i?" We would get $n \times n$ adjacent matrix X that is called the direct matrix. The (i, j) element x_{ij} of this matrix denotes the amount of direct influence from factor i to factor j. If the direct matrix X is normalizes as $X_r = \lambda X$, by using $\lambda = 1/$(the largest row sum of X), we would obtain

$$X^f = X_r + X_r^2 + \cdots = X_r(I - X_r)^{-1}. \tag{1}$$

Matrix X^f is called the direct/indirect matrix. The (i, j) element x_{ij}^f of the direct/indirect matrix denotes the amount of direct and indirect influence from factor i to factor j.

Suppose D_i denotes the row sum of ith row of matrix X^f. Then, D_i shows the sum of influence dispatching from factor i to the other factors both directly and indirectly. Suppose R_i denotes the column sum of ith column of matrix X^f. Then, R_i shows the sum of influence that factor i is receiving from the other factors. Furthermore, the sum of row sum and column sum $(D_i + R_i)$ shows the index representing the strength of influence both dispatching and receiving, that is, $(D_i + R_i)$ shows the degree of central role that the factor i plays in the problematique. If $(D_i - R_i)$ is positive, then the factor i is rather dispatching the influence to the other factors, and if negative, then the factor i is rather receiving the influence from the other factors. We call D_i, R_i, $(D_i + R_i)$ and $(D_i - R_i)$ the degree of dispatching influences, the degree of receiving influences, the degree of central role and the degree of cause, respectively.

There exist many case studies [5–10] of DEMATEL to get an appropriate structural model. Some of them are trying to get a structural model identifying the central factors and the causing factors based on the evaluation of the degree of central role and the degree of cause. The degree of cause denotes whether the factor is rather cause or effect. It does not reflect the amount of dispatching or receiving influence. Since the objective of this paper is to find the priority of the strategy to improve the overall structure, we turn our attention to the degree of dispatching influences.

2.2. Composite importance

Suppose based on the degree of dispatching influences we found a factor that may contribute to improve the overall structure. In this case to resolve this factor is not necessarily the best choice, since the factor that could contribute to resolve some important factors may be more efficient to resolve even if it may not contribute to improve overall structure. Since the original DEMATEL is not taking into account the importance of each factor itself, it is not possible to evaluate the priority among the factors. Similarly, it is not possible to evaluate the priority of each factor by just looking at the importance of each factor. We need to take into account both the strength of relationships among factors and the importance of each factor. To reflect both viewpoint we proposed the composite importance z as [4]

$$z = y_r + X^f y_r = (I + X^f) y_r, \tag{2}$$

where y_r denotes the normalized n-dimensional vector of y that denotes n-dimensional vector composed of the importance of each factor, where "normalized" means to divide each element of y by the largest element in y.

3. Stochastic DEMATEL

3.1. Stochastic direct matrix

In the ordinary DEMATEL the direct influence from factor i to factor j is written in the (i, j) element x_{ij} of the direct matrix X. Suppose the structure of the problematique is uncertain and x_{ij} is a random variable. Furthermore, suppose the stochastic parameter values of x_{ij} are different for different pair of i and j. When each element of the direct matrix is a random variable, each element of the direct/indirect matrix X^f is also a random variable. Furthermore, the composite importance z is also a random variable. Therefore, it is necessary to extend the ordinary DEMATEL to deal with uncertainty in the problem structure. We propose a stochastic DEMATEL in which we could take care of various uncertainties in the problem structure.

In stochastic DEMATEL let G be a set of stochastic direct matrices X^s generated by a Monte Carlo method from the direct matrix X^v with probabilistic information. The direct matrix with probabilistic information is an $n \times n$ matrix with (i, j) element x_{ij} and probability density function $g(x_{ij}|\theta_{ij})$, where θ_{ij} denotes the parameter including expectation and variance.

As described above in the ordinary DEMATEL we could get the element of direct matrix by asking such a question as "How much would it contribute to resolve factor j by resolving factor I?" On the other hand in the stochastic DEMATEL we need to collect the information on the variance as well as on the expectation of influence. Possible methods to collect information on variance are as follows:

- **Method 1.** We ask a respondent the best value and the worst value, by asking "How much would it contribute to resolve factor j at most by resolving factor i, and how much would it contribute to resolve factor j at least by resolving factor I?" From the best value and the worst value we could estimate the variance.
- **Method 2.** We ask multiple respondents on the value of direct matrix and compute the variance from these multiple direct matrices.

- **Method 3.** We combine Method 1 and Method 2. We ask each respondent the best value and the worst value of each element of the direct matrix. Then, we aggregate these data and estimate the variance of each element of the direct matrix.

3.2. Manipulation in stochastic DEMATEL

We normalize the stochastic direct matrix as

$$X_r^s = \lambda \cdot X^s, \tag{3}$$

where

$$\lambda = 1/(\text{the largest row sum of } X^s).$$

Then we obtain

$$X^{sf} = X_r^s + (X_r^s)^2 + \cdots = X_r^s (I - X_r^s)^{-1}, \tag{4}$$

where X^{sf} denotes a stochastic direct/indirect matrix that has the same property as the ordinary direct/indirect matrix. Stochastic composite importance is obtained as

$$z^s = y_r + X^{sf} y_r = (I + X^{sf}) y_r. \tag{5}$$

If we obtain stochastic direct/indirect matrices and stochastic composite importance for all the direct matrices contained in the set G, we could obtain the set G^f of the direct/indirect matrices and the set G^z of composite importance. Furthermore, we could obtain the set of the degree of dispatching, the set of the degree of receiving, the set of the degree of central role and the set of the degree of cause, respectively.

4. A simple numerical experiment

4.1. Structural modeling by stochastic DEMATEL

Suppose an overall structure is composed of three factors a, b and c, and the direct matrix is given by

$$X_e = \begin{bmatrix} 0 & 2 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}. \tag{6}$$

In this structure factors a and b are mutually influenced, factor c is influenced by factor a, and factor b is influenced by factor c. Therefore, factor b is influenced by factor a both directly and indirectly. The intensity of direct influence is the largest from factor a to factor b.

As the degree of dispatching influences and the degree of central role, we obtained for factor a: 1.85 and 2.80, for factor b: 0.95 and 2.80 and for factor c: 0.65 and 1.30. As for the degree of dispatching influences, factor a is the largest and factor b is the next. Both factors a and b are the central factors, factor a is a cause factor and factor b is an effect factor. Suppose the structure of this simple numerical example is uncertain. Suppose besides the information on expectation given by the direct matrix, variance for each element is given by

$$Var_e = \begin{bmatrix} 0 & 0.04 & 0.04 \\ 0.04 & 0 & 0 \\ 0 & 0.04 & 0 \end{bmatrix}, \tag{7}$$

where the dispersion of the influence from factor a to factor b is assumed to be relatively small. It is assumed that cutting normal distribution between zero and infinity is assumed for probability density function.

We generated 1000 elements of a set G by using Monte Carlo method. Then, for each element of the set G, that is, for each stochastic direct matrix X_i^s ($i = 1, 2, \ldots, 1000$), we could obtain stochastic direct/indirect matrix and a set G^f.

Figure 1 shows the degree of dispatching influences and the degree of receiving influences obtained from the stochastic direct/indirect matrices. As seen in this figure the degree of dispatching influences of factor a is big and the degree of receiving influences of factor b is big. As the expectation (and the variance in the parenthesis) of the degree of dispatching influences and the degree of receiving influences we obtained for factor a: 1.8907 (0.0694), 1.0006 (0.1079), for factor b: 0.9936 (0.0966), 1.9064 (0.1167) and for factor c: 0.6805 (0.0418), 0.6577 (0.0175).

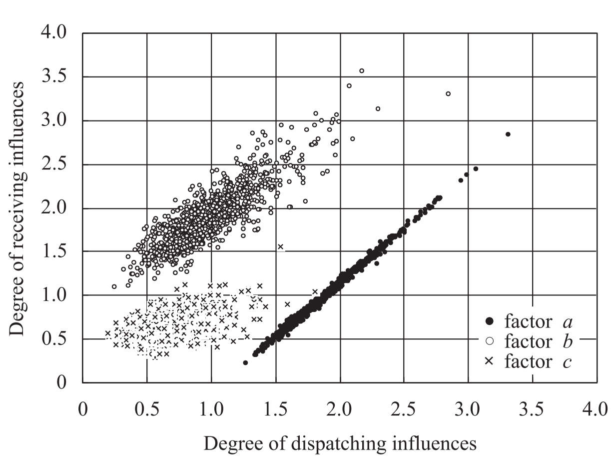

Fig. 1. Degree of dispatching influences and degree of receiving influences.

For factor a and factor b we found a big positive correlation between the degree of dispatching influences and the degree of receiving influences especially for factor a. The reason is that for both factors when they affect the other factor, the influence is fed back to themselves directly. On the other hand for factor c since the influence is fed back to itself indirectly, we did not find a big correlation (correlation coefficient = 0.51) between the degree of dispatching influences and the degree of receiving influences.

Table 1
Stochastic composite importance (numerical experiment)

Factors	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
Importance	0.4	0.4	0.4	0.3	0.1	0.7	0.1	0.7	0.4
Expected value	1.1563	0.7974	0.6722	0.8332	0.3860	0.8320	1.0670	1.0670	0.7637
2.5 percentile	0.9910	0.5936	0.5411	0.7049	0.2409	0.7622	0.9011	0.8791	0.5949
25 percentile	1.0822	0.7125	0.6166	0.7825	0.3254	0.7993	0.9930	0.9869	0.6973
Median	1.1414	0.7778	0.6621	0.8252	0.3733	0.8247	1.0549	1.0521	0.7544
75 percentile	1.2114	0.8658	0.7158	0.8748	0.4373	0.8550	1.1216	1.1313	0.8192
97.5 percentile	1.4006	1.0882	0.8679	1.0079	0.5971	0.9403	1.3114	1.3354	0.9915
CV	0.0911	0.1559	0.1216	0.0902	0.2283	0.0560	0.0992	0.1093	0.1290

In Fig. 1 we could draw many lines with gradient -1. The points on the same line have the same degree of central role, and the point located upper right side has a bigger degree of central role than the points on the line. These lines denote the indifference lines of the degree of central role. By using these indifference lines we could find that factors *a* and *b* are the central factors. As the expectations of the degree of central role we found for factors *a*, *b* and *c*: 2.8914, 2.9000 and 1.3382, respectively.

Next, we draw a line passing through the origin with gradient 1 in Fig. 1. Then, the points located lower right side of this line are the "cause" factors and the points located upper left side of this line are the "effect" factors. This fact implies that in every stochastic direct/indirect matrix it is found that factor *a* is a cause factor and factor *b* is an effect factor. Factor *c* is a cause factor or effect factor case by case.

If we compare the degree of dispatching influences, the degree of receiving influences and the degree of central role for ordinary DEMATEL and for stochastic DEMATEL, these values are almost identical. The values for stochastic DEMATEL are slightly larger than those for the ordinary DEMATEL. If we could find a precise probability distribution function and if we could generate infinitely many random numbers precisely, the expectation for both DEMATELs should agree each other in principle.

We found that we could get a proper structural model of a complex problematique under uncertainty by using the degree of dispatching influences and the degree of central role of the stochastic DEMATEL proposed in this paper.

4.2. Stochastic composite importance

If we assign the value of importance of each factor, we could evaluate the stochastic composite importance. Since we obtain 1000 values for each factor, we summarize the result in Table 1: percentiles (2.5%, 25%, median, 75%, 97.5%), expectation and coefficient of variation (*CV* = standard deviation/expectation).

In the ordinary DEMATEL we could decide the priority of each factor based on the value of composite importance itself. In the stochastic DEMATEL we use three stochastic decision principles as follows:

- **Expectation principle.** We decide the priority based on the expected value or median of composite importance.
- **Max-min principle.** We decide the priority of each factor by maximizing the worst value (either 2.5 percentile or 25 percentile) of composite importance. This principle reflects a pessimistic decision.
- **Max-max principle.** We decide the priority of each factor by maximizing the best value (either 75 percentile or 97.5 percentile) of composite importance. This principle reflects an optimistic decision.

As seen in Table 1 when the importance of each factor is 0.4, the composite importance of factor *a* is the largest under any of these three decision principles, therefore, the highest priority is given to factor *a*. When the importance of factors *a*, *b* and *c* is 0.3, 0.1 and 0.7, respectively, the priority of factor *a* is higher under the expectation principle and max-max principle, and the priority of factor *c* is slightly higher under the max-min principle. When the importance of factors *a*, *b* and *c* is 0.1, 0.7 and 0.4, respectively, the priority of factors *a* and *b* is higher under the expectation principle, the priority of factor *a* is higher under the max-min principle and the priority of factor *b* is higher under the max-max principle. In this case under the attitude of pessimistic decision, factor *a* is chosen to be resolved, and under the attitude of optimistic decision, factor *b* is chosen to be resolved. In this case the expectation for factors *a* and *b* is almost identical, *CV* for factor *a* is smaller than that for factor *b*, and factor *a* is chosen under the max-min principle and factor *b* is chosen under the max-max principle. This implies that the priority decided by max-min principle and max-max principle depends on the variance of composite importance of each factor.

As seen above the stochastic DEMATEL could describe the uncertainty of the structure of complex problematique, could describe the uncertainty of priority by the stochastic composite importance and could decide the priority of each factor reflecting the decision makers attitude whether he/she is pessimistic, neutral or optimistic.

5. Structural modeling of uneasy factors by stochastic DEMATEL

5.1. Data

We use the data previously obtained from university students and unmarried adults [4].
For university students 10 uneasy factors are chosen as follows:

1. Career to pursue (CAR)
2. Scholastic performance (SCH)
3. Home economy (HOE)
4. Health of myself (HEM)
5. Health of family (HEF)
6. Marriage (MAR)
7. Looks (LOO)
8. Ability/character (ABI)
9. Human relations (HUR)
10. Job and work (JAW)

For unmarried adults 9 uneasy factors are chosen as follows:

1. Home economy
2. Health of myself (HEM)
3. Health of family (HEF)
4. Unemployment (UNE)
5. Marriage (MAR)
6. Looks (LOO)
7. Ability/character (ABI)
8. Human relations (HUR)
9. Job and work (JAW)

Respondents to the questionnaire are 10 university students and 10 unmarried adults. The importance of each factor is asked to the respondents by 5-grade evaluation where the importance of each factor means the degree of feeling uneasy for each factor. Then, the strength of binary relation for each pair of factors is asked by 3-grade evaluation, We look at the binary relation such that "How much would it contribute to resolve factor *b* (the anxiety for SCH) by resolving factor *a* (the anxiety for CAR) ?"
The direct matrix is obtained by averaging the data of 10 people on the strength of binary relations. The data for the importance of each factor are first normalized between 0 and 1 and then averaged for 10 people.
Structural model for uneasy factors of university students is described as follows: the degree of central role for CAR (4.75) is high and CAR has the property of both cause factor and effect factor, but since the degree of cause for CAR (−0.35) is negative, CAR is rather an effect factor. Actually, CAR is greatly affected by ABI, SCH, HOE and JAW.
Besides CAR the degree of central role for HOE (3.63), ABI (3.63), JAW (3.54) and SCH (3.35) are high. Especially, the degree of cause for ABI (1.41) is high, this is a central factor with the property of cause factor.
Structural model for uneasy factors of unmarried adult is described as follows: the degree of central role for JAW (6.07) is high, and then ABI (5.79), HOE (5.40). JAW and ABI are mainly cause factor, however, they have the property of effect factor as well. On the other hand HOE is affected by UNE, JAW and others, and has the property of effect factor.
In Table 2 the degree of dispatching influences and composite importance of university students and unmarried adults are shown. Concerned with the degree of dispatching influences ABI, CAR are high for university students and ABI, JAW, HEM are high for unmarried adults with this order. Concerned with the composite importance CAR, ABI are high for university students and ABI, JAW, HEM are high for unmarried adults with this order. This implies that by resolving these factors overall uneasiness is resolved enormously.
We need to pay attention that for university students the order of factors for the degree of dispatching influences is different from the order of factors for the composite importance. The reason why is that in the composite importance the degree of dispatching influences as well as the importance of each factor and the importance of affecting factors are reflected. For example the degree of dispatching influences of CAR is not so high, but since the importance of CAR is high, the composite importance of CAR is high in consequence. Therefore, it is clarified that from the view point of importance CAR is to be resolved and from the view point of dispatching influences ABI is to be resolved.

5.2. Structural modeling by stochastic DEMATEL

Suppose the structure of the uneasy factors is uncertain. Expectation and variance of probability distribution is obtained by the dispersion of the data contained in multiple respondents reply in the direct matrix. Probability density function is assumed to be a cutting normal distribution defined on $[0,\infty)$. Based on these probabilistic information 1000 stochastic direct matrices are generated by using a Monte Carlo method.
Tables 3 and 4 show a structural model extracted by the stochastic DEMATEL from the uneasy factors of university students and unmarried adults, respectively. The ex-

Table 2
Composite importance

Factors		CAR	SCH	HOE	HEM	HEF	UNE	MAR	LOO	ABI	HUR	JAW
Students	*D*	2.200	1.643	1.825	1.052	0.607		0.866	0.753	2.521	1.510	1.826
	Importance	0.675	0.550	0.600	0.350	0.400		0.500	0.450	0.500	0.450	0.425
	CI	1.796	1.411	1.527	0.894	0.706		0.928	0.842	1.794	1.232	1.374
Adults	*D*			2.167	3.041	1.324	1.565	1.824	1.553	3.307	2.529	3.243
	Importance			0.475	0.550	0.550	0.400	0.425	0.550	0.600	0.425	0.475
	CI			1.528	2.028	1.182	1.163	1.316	1.299	2.189	1.659	2.048

Table 3
Structural extraction by stochastic DEMATEL (university students)

Values		CAR	SCH	HOE	HEM	HEF	MAR	LOO	ABI	HUR	JAW
D	Expected	2.248	1.818	2.217	1.613	0.948	1.422	1.063	2.523	1.859	2.296
	Median	2.140	1.679	2.156	1.472	0.861	1.290	0.947	2.456	1.730	2.254
	CV	0.359	0.422	0.347	0.427	0.466	0.439	0.511	0.263	0.404	0.342
$D+R$	Expected	4.934	3.799	4.286	3.044	2.112	2.706	3.209	3.939	3.762	4.223
	Median	4.689	3.570	4.031	2.809	1.926	2.505	2.953	3.753	3.454	4.023
	CV	0.339	0.366	0.341	0.368	0.398	0.381	0.383	0.294	0.365	0.337

Table 4
Structural extraction by stochastic DEMATEL (unmarried adults)

Values		HOE	HEM	HEF	UNE	MAR	LOO	ABI	HUR	JAW
D	Expected	2.181	2.630	1.661	1.734	1.970	1.813	2.772	2.268	2.703
	Median	1.992	2.551	1.490	1.571	1.767	1.634	2.665	2.089	2.601
	CV	0.453	0.345	0.486	0.484	0.476	0.498	0.341	0.447	0.362
$D+R$	Expected	4.820	4.283	3.347	3.987	4.495	3.696	5.074	4.575	5.182
	Median	4.453	4.015	3.035	3.656	4.136	3.372	4.779	4.305	4.815
	CV	0.405	0.368	0.433	0.422	0.416	0.427	0.368	0.405	0.385

pected value obtained in these tables did not agree with the results obtained by the ordinary DEMATEL. Since the expected value and median are little bit different, the assumption of cutting normal distribution may not be appropriate. However, since concerned with the order of the degree of dispatching influences (D) and the degree of central role ($D+R$) the result obtained by the stochastic DEMATEL gave a good agreement with the result obtained by the ordinary DEMATEL, the stochastic DEMATEL is appropriate to extract the property of the structural model.

Since the value of coefficient of variation (CV) is around 0.4, the uncertainty of the structure is fairly big. If we look at CV of D and $D+R$ for each factor, we find that CV of D and $D+R$ for ABI is smaller than for the other factors and CV of D and $D+R$ for LOO is large for university students. This implies that by resolving ABI university students could expect a stable effect, but by resolving LOO university students should anticipate uncertain effect. For unmarried adults CV of D and $D+R$ for ABI and HOM is small and the variation of CV depending upon the different factors is relatively small.

5.3. Stochastic composite importance

In Tables 5 and 6 stochastic composite importance of each factor for university students and unmarried adults is shown, respectively.

For university students composite importance, that is, the priority of CAR, ABI and HOE are large with this order under the expectation principle and max-max principle, where the priority of ABI and HOE is reversed for 97.5 percentile. This is due to the fact that CV for HOE is larger than that for ABI. Under the expectation principle the priority obtained by the stochastic DEMATEL gave a good agreement with the priority obtained by the ordinary DEMATEL. This result implies that reliability of the stochastic com-

Table 5
Stochastic composite importance (university students)

Values	CAR	SCH	HOE	HEM	HEF	MAR	LOO	ABI	HUR	JAW
Expected	1.804	1.482	1.708	1.171	0.880	1.201	0.994	1.775	1.394	1.593
2.5 percentile	1.170	0.935	1.079	0.719	0.561	0.777	0.630	1.188	0.841	0.914
25 percentile	1.495	1.207	1.425	0.917	0.722	0.969	0.807	1.561	1.124	1.293
Median	1.752	1.411	1.671	1.093	0.834	1.134	0.938	1.741	1.328	1.566
75 percentile	2.053	1.676	1.935	1.365	0.995	1.370	1.112	1.956	1.591	1.846
97.5 percentile	2.726	2.392	2.574	2.001	1.475	1.976	1.725	2.497	2.348	2.454
CV	0.226	0.266	0.228	0.300	0.254	0.259	0.280	0.190	0.274	0.252

Table 6
Stochastic composite importance (unmarried adults)

Values	HOE	HEM	HEF	UNE	MAR	LOO	ABI	HUR	JAW
Expected	1.540	1.836	1.351	1.252	1.394	1.434	1.942	1.540	1.795
2.5 percentile	0.898	1.104	0.855	0.736	0.827	0.895	1.195	0.856	1.050
25 percentile	1.186	1.541	1.078	0.970	1.075	1.124	1.645	1.175	1.458
Median	1.449	1.801	1.266	1.177	1.292	1.345	1.889	1.454	1.739
75 percentile	1.795	2.080	1.522	1.442	1.593	1.635	2.196	1.808	2.074
97.5 percentile	2.636	2.740	2.294	2.231	2.554	2.573	2.923	2.664	2.779
CV	0.314	0.243	0.290	0.329	0.331	0.309	0.239	0.324	0.268

posite importance obtained by the stochastic DEMATEL is quite high.

Under the max-min principle the priority of ABI is the highest and then that of CAR and HOE. The reason why the priority of ABI is the highest is that the max-min principle reflects the pessimistic attitude of decision and that *CV* of D for ABI is small, and as the result *CV* of composite importance is also small. This will lead to the expectation of certain effect by resolving uneasiness of ABI.

For unmarried adults the priority of ABI, HEM and JAW are large with this order under all the three principles except that for 97.5 percentile the priority of JAW and HEM is reversed. This order of priority obtained by the stochastic composite importance is different from that obtained by the composite importance of ordinary DEMATEL: ABI, JAW and HEM. The reason why we get this result is that for unmarried adults the elements of the stochastic direct matrices are smaller than those of the direct matrix. As the result each element of the degree of dispatching influences (D) is reduced to be relatively small. As we know the composite importance reflects both D and importance of each factor. Since the value of D is reduced to be relatively small in the stochastic composite importance, weight for D is reduced to be smaller than that for importance of each factor. As the result, in the stochastic DEMATEL the priority of HEM became higher than that of JAW, because the importance of HEM is larger than that of JAW for unmarried adults.

The reason why the elements of the stochastic direct matrices are smaller than those of the direct matrix may be due to the error arisen from inappropriate assumption of probability density function. Although this error does not cause serious defects when we evaluate the degree of dispatching influences (D) and the degree of central role ($D+R$), we may get some defects when we evaluate composite importance. Therefore, to overcome this difficulties we need to develop a method of identifying appropriate probability distribution function or to develop a non-parametric approach.

6. Concluding remarks

In this paper a stochastic DEMATEL is proposed for structural modeling of a complex problematique taking into account the uncertainty of structure. This method is obtained by extending the deterministic variables in the ordinary DEMATEL to random variables. To show the validity of the method a simple numerical example and a structural modeling of uneasy factors are included for the purpose of realizing safe, secure and reliable society.

New knowledge obtained in this study is as follows:

- Stochastic DEMATEL could extract the characteristics of the structure even when there exist uncertainty in the structure.
- Stochastic composite importance could describe the uncertainty of priority arising from the uncertainty of the structure, and could decide the priority taking into account the attitude of the decision maker towards risk; pessimistic, neutral or optimistic.

- In order to resolve uneasy factors of university students uneasiness of CAR and ABI is efficient to be resolved. CAR is to be resolved from the view point of the importance of the factor and ABI is to be resolved from the view point of the degree of dispatching influences. When the decision maker's attitude toward risk is pessimistic, it is desirable to resolve the uneasiness of ABI, since certain effect can be expected by doing so.
- To resolve the uneasiness of ABI is the most effective for unmarried adults.

It is demonstrated above that the stochastic DEMATEL and the information obtained by the stochastic composite importance are quite useful for structural modeling of complex problematique.

For further study we need to develop a method of identifying appropriate probability distribution function or we need to develop a non-parametric approach. We also need to develop a method of collecting information on variance. For these purposes we need to experience more empirical analysis of various case studies.

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