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Research Article

Improvements in Interface Cohesion Evaluation Method for DSM Clustering Analysis

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Abstract: Design Structure Matrix clustering analysis requires reliable evaluation results of interface cohesion among interfacing elements to produce an effective result. However, the existing cohesion evaluation methods such as the Pimmler and Eppinger's or Sharman's can provide biased subjective evaluation results depending on the characteristics of the individual evaluator. In this study, we propose a new quantitative evaluation method for the interface cohesion based on the amount of information being exchanged among the interfacing elements. The study shows the comparison results for interface cohesion evaluation between those of the existing methods and the new method to demonstrate the merits of the proposed method.

Keywords: Clustering, DSM, entrophy, interface cohesion

INTRODUCTION

Design Structure Matrix (DSM) implements design structure for system modeling in the form of matrix and generally applied to clustering analysis (Browning, 2001). Clustering analysis allows elements with close interface relationship to be grouped into a cluster and can minimize interface among multiple clusters created as a result. This method is useful very much for analyzing modularization of complex systems (Yassine, 2004). To obtain excellent results through this analysis, scores of reliable interface cohesion grade need to be input. Although this process is very important, a considerable number of studies thus far have placed primary focus on improving the analysis algorithms. This study examined problems inherent in conventional methods for evaluation of interface cohesion, instead of algorithm.

Regarding the two methods used most commonly to evaluate inter-element interface cohesion, Pimmler and Eppinger (1994) presented the method by which users feed and add up the level of interactive importance that they would assign to inter-element spatial arrangement, exchange of energy, exchange of information and exchange of materials to calculate the sum. This level of importance can be quantified based on the scale such as "very important", "important", "moderate", etc. This method has the advantage of ensuring accuracy of evaluation through qualitative evaluation by interface and therefore has been used in many studies (Cabrera *et al*., 2014; Chakrabarti *et al*., 2011; Fixson and Park, 2008; Li and Mirhosseini, 2012; Pil and Cohen, 2006; Stone *et al*., 2000; Yassine and Braha, 2003).

Sharman (2002) simply added up the presence or absence of the 4 relationship types described above. This method enables easy evaluation of interface cohesion and has found wide-ranging application to the Design Structure Matrix (DSM) clustering analysis (Börjesson, 2012; Baldwin and Clark, 2002; Borjesson and Hölttä-Otto, 2012, 2014; Ko, 2013; Oh and Park, 2015; Yu *et al*., 2003, 2007). Those methods have simplicity of evaluation technique or high reliability, but have respective problems.

Problems with Pimmler's evaluation method: Pimmler's cohesion evaluation method is determined by the subjectivity of analyst. In other words, different results can be derived based on disparate perspectives of multiple evaluators who evaluate same target system. For example, the exchange of air occurs in materials such as HVAC-Passenger Interface of train. For energy, heat exchange occurs. This is very important and high scores can be assigned if passenger-based approach is taken. By contrast, low scores can be assigned if the approach is based on transportation, the functionality of train. Moreover, different results can be derived, depending on the difference in the intensity of "feeling towards individual interfaces of analyst", even if the approach is taken based on same perspective. Therefore, cross-checking of results is needed to derive reliable quantitative value through qualitative evaluation. However, that requires patience. To derive reliable results through Pimmler' evaluation method, coordination is required with commitment of much time for the area of disagreement within IPDT comprised of multiple analysts.

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Problems with Shaman's evaluation method: As Sharman's evaluation method is much simpler than Pimmler's, the advantage of Sharman's evaluation is that it is free of problems inherent in evaluation methods and allows the results to be derived more quickly, which makes Sharman's evaluation method very useful. However, this method considers only presence or absence of correlation between components and therefore reliability of results may be compromised slightly. For example, when information signal is considered as criteria, no difference is made between multiple information items and single information item within a link, considering both types identical. This is not consistent with the concept of modularization that the inside of cluster should have maximum cohesion. In this study, we applied the information theory concept of Shannon (2001) to resolve the problems presented above.

METHODOLOGY

Definition of criteria for evaluating interface cohesion: The purpose of clustering is to modularize system components. Parnas (2002) explained the 3 conditions necessary for modularization as below:

Moderate complexity: The architecture of module should be understandable by stakeholders.

Minimal coupling: Impact on other modules should be minimized.

Maximum cohesion: Correlation between functions and data present in module should be maximized.

According to the concept described above, modular and inter-modular interface requirements should be minimized to ensure independence of individual modules.

In the event of high interface cohesion among unit components which implies existence of many interface requirements, it would be desirable to divide them into groups. That can make understanding easier from the standpoint of management. If interface requirements of certain modules are reduced in quantity, the workload of ICWG (Interface Control Working Group) would be also alleviated for concerned module. Moreover, it means higher independence of other modules from design alteration of concerned module. In this study, we used the quantity of interface requirements as criteria for cohesion, instead of the level of importance for the 4 correlation types presented by Pimmler.

Definition of information quantity for clustering analysis: In this section, we intend to define the information quantity for interface cohesion based on quantity of interface requirements. Above all, information quantity of interface requirement cohesion may determine fulfillment or non-fulfillment of interface requirements based on the perspective of ICWG. The intention to guarantee fulfillment of interface requirements is the underlying reason for managing the requirement of interface present in ICD, along with the management of impact of interface which arises from the change in the form of specific module.

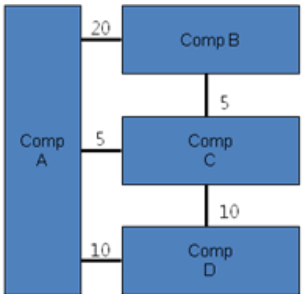


Fig. 1: Quantity of interface requirements among subcomponents

In this study, the information quantity of inter-element interface (I) was calculated by using the following Eq. (1):

$$I = -\log_2\left(1 - \frac{C_c}{C_t}\right) \tag{1}$$

Here, Ct represents quantity of overall requirements. In addition, Cc represents inter-component interface requirement.

This means the rate of interface achievement which assumed failure of all requirements of specific interface when entire system is considered to be the criteria. If there are multiple interface requirements among components, the rate of interface achievement will be reduced accordingly. This suggests that information quantity increases accordingly. If there is no interface requirement among certain components, information quantity becomes zero (0). Additionally, information quantity will increase sharply when inter-component interface requirement increases.

Example of information quantity application for clustering analysis: Figure 1 shows quantity of interface requirements among subcomponents of certain system. It is assumed that this system which consists of 4 components (A, B, C and D) has 50 interface requirements in all and that internal interface cohesion of components B, C and D is identical. If component A needs to be modularized with one of the components B, C and D, we know from previous experience that it would be desirable to have the component a modularized with component B that has the largest number of interface requirements.

Figure 2 is the representation of Fig. 1 based on information quantity. Based on that, it can be found that information quantity of interface between component A and B is far higher than information quantity of other

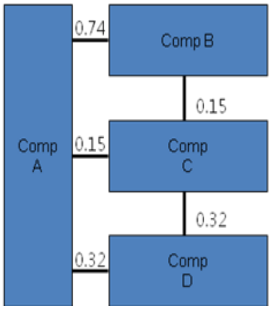


Fig. 2: Representation based on information quantity

interfaces. Therefore, it would be desirable to ensure modularization between components A-B which have the largest number of interface cohesion information quantity.

Method for verification: in this chapter, we compared the results of clustering analysis based on the scores of interface cohesion evaluation for some components of train system. For the verification test, scores were determined by 9 experts from KRRI (Korea Railroad Research Institute) through Pimmler's evaluation method and Sharman's evaluation method. The cohesion scores were estimated by putting together the result sheets and cross-checking. Then, the quantity of interface requirements identified by ICD of concerned system component was figured out, followed by the estimation of cohesion score through the proposed evaluation method of the author. Clustering analysis was performed based on the results of the two evaluation methods.

The improvement ratio is derived by comparing the modularization scores assigned before and after analysis. The modularization scores were calculated by using the formula (Sharman *et al*., 2002) (2), (3), (4):

$$\text{Intra Cl Cost} = \big(\text{DSM}(j,k) + \text{DSM}(k,j)\big) * \text{Cl Size}(y) \tag{2}$$

$$\text{Extra Cl Cost} = \big(\text{DSM}(j,k) + \text{DSM}(k,j)\big) * \text{DSM Size} \tag{3}$$

$$\text{Total Cost} = \sum_{k=1}^{N} \text{Intra Cl Cost} + \sum_{k=1}^{N} \text{Extra Cl Cost} \tag{4}$$

Here, Intra Cluster Cost refers to the cost of correlation arising from within the cluster. Extra Cluster Cost refers to the cost of correlation arising from the outside of cluster. Total Cost refers to the cost incurred from integration of both cluster costs. The lower the total cost is, the better the modularization has been achieved.

RESULTS

Application of Pimmler's evaluation method: Figure 3 shows the sum of each score (score ranging from 1 to 10 on the scale of importance) after evaluating the importance for space, information, energy and materials, according to the definition of

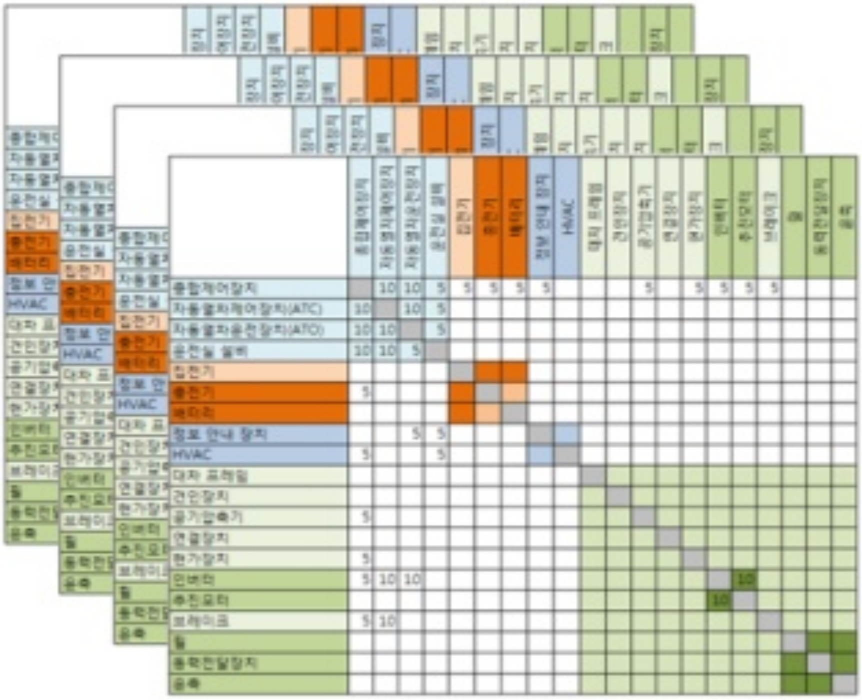
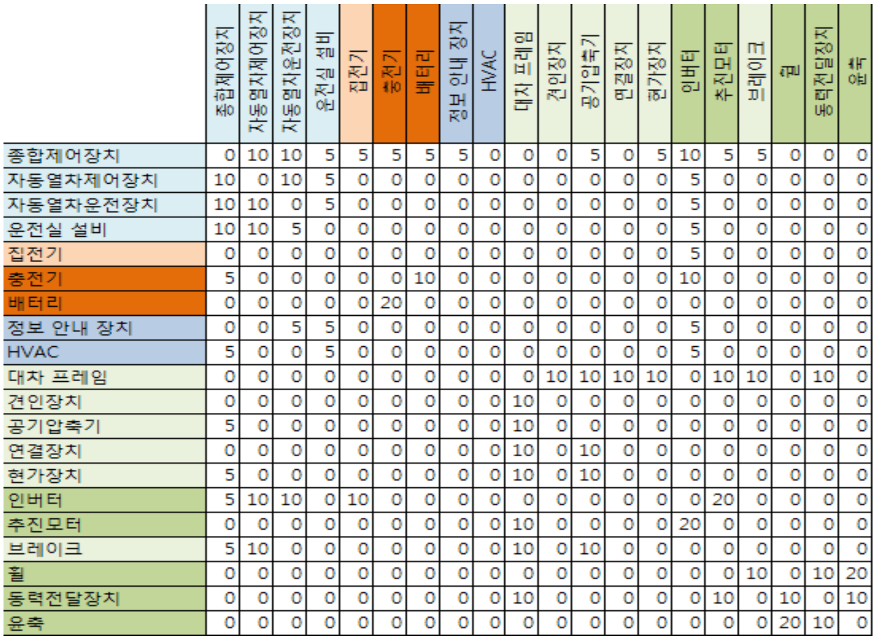
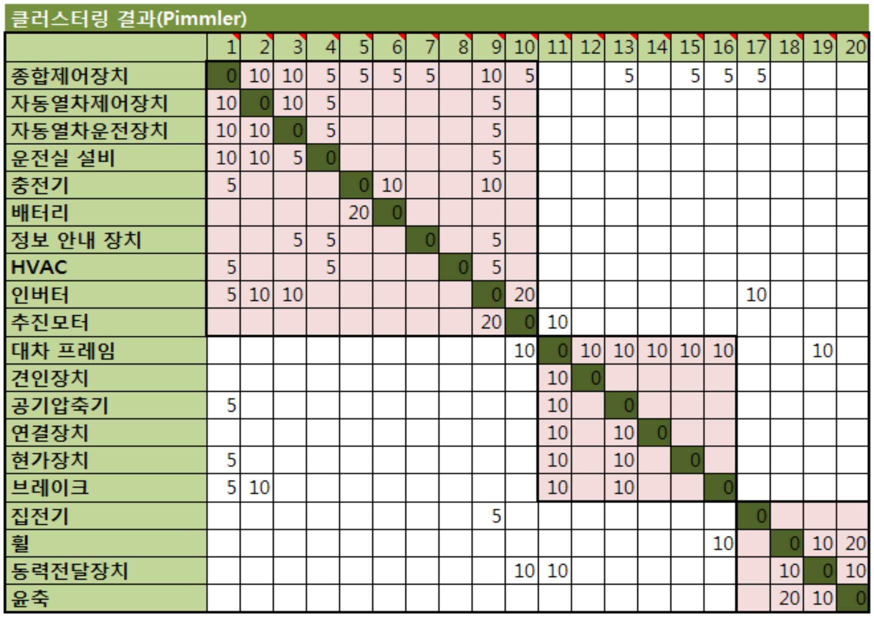


Fig. 3: Sum of each score after evaluating the importance for 4 Criteria



	종합제어장치	자동열차제어장치	자동열차운전장치	운전실 설비	집전기	충전기	배터리	정보 안내 장치	HVAC	대차 프레임	견인장치	공기압축기	연결장치	현가장치	인버터	추진모터	브레이크	휠	동력전달장치	윤축
종합제어장치	0	10	10	5	5	5	5	5	0	0	0	5	0	5	10	5	5	0	0	0
자동열차제어장치	10	0	10	5	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
자동열차운전장치	10	10	0	5	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
운전실 설비	10	10	5	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
집전기	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
충전기	5	0	0	0	0	0	10	0	0	0	0	0	0	0	10	0	0	0	0	0
배터리	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
정보 안내 장치	0	0	5	5	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
HVAC	5	0	0	5	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
대차 프레임	0	0	0	0	0	0	0	0	0	0	10	10	10	10	0	10	10	0	10	0
견인장치	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0
공기압축기	5	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0
연결장치	0	0	0	0	0	0	0	0	0	10	0	10	0	0	0	0	0	0	0	0
현가장치	5	0	0	0	0	0	0	0	0	10	0	10	0	0	0	0	0	0	0	0
인버터	5	10	10	0	10	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0
추진모터	0	0	0	0	0	0	0	0	0	10	0	0	0	0	20	0	0	0	0	0
브레이크	5	10	0	0	0	0	0	0	0	10	0	10	0	0	0	0	0	0	0	0
휠	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	10	20
동력전달장치	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	10	0	10	0	10
윤축	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	10	0

Fig. 4: DSM sheet added up the results



클러스터링 결과(Pimmler)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
종합제어장치	0	10	10	5	5	5	5		10	5			5		5	5	5			
자동열차제어장치	10	0	10	5					5											
자동열차운전장치	10	10	0	5					5											
운전실 설비	10	10	5	0					5											
충전기	5				0	10			10											
배터리					20	0														
정보 안내 장치			5	5			0		5											
HVAC	5			5				0	5											
인버터	5	10	10						0	20							10			
추진모터									20	0	10									
대차 프레임										10	0	10	10	10	10	10			10	
견인장치											10	0								
공기압축기	5										10		0							
연결장치											10		10	0						
현가장치	5										10		10		0					
브레이크	5	10									10		10			0				
집전기									5								0			
휠																10		0	10	20
동력전달장치										10	10							10	0	10
윤축																		20	10	0

Fig. 5: Result of DSM clustering analysis

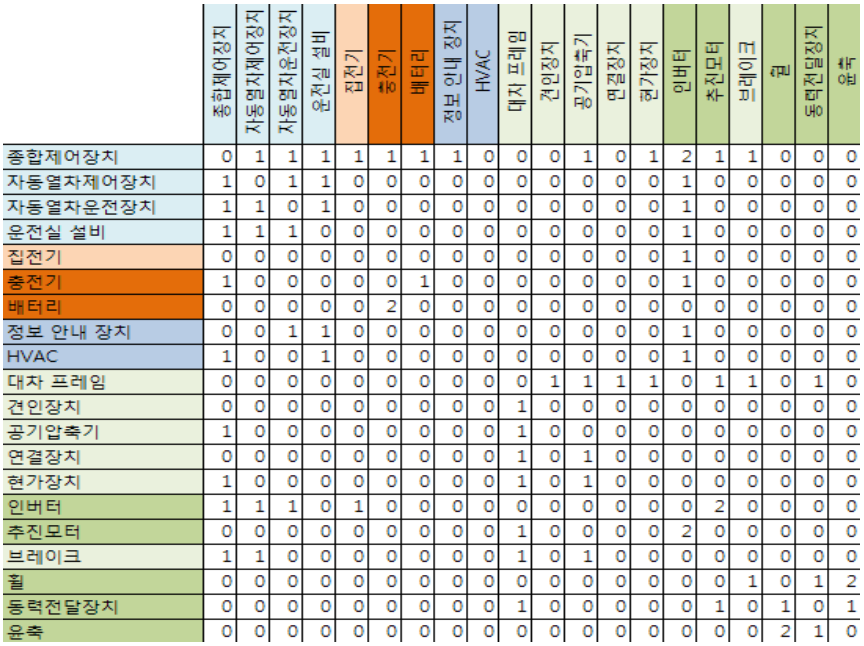
Pimmler. Figure 4 shows the DSM sheet adding up the results of evaluation of 5 correlation types.

The results of DSM Clustering Analysis based on aforesaid sheet are presented in Fig. 5. It was found that 51.62% improvement was achieved when the modularization scores were calculated based on the results as derived above:

- Before the Clustering Analysis: 12,300
- After Clustering Analysis: 5,960
- Modular ratio: 51.62%

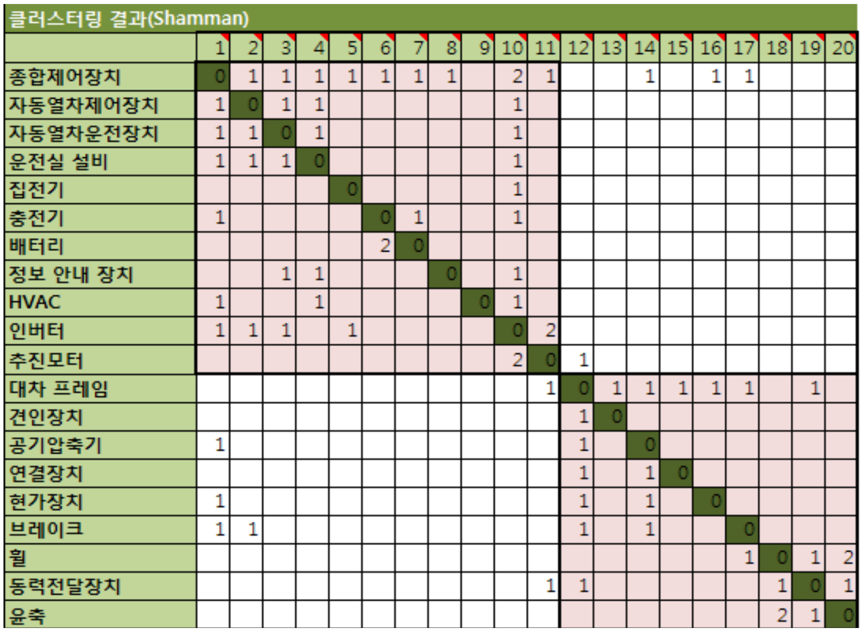
Application of sharman's evaluation method: Under Sharman's evaluation method, cluster analysis is conducted based on the results derived by adding up the presence or absence of interface for space, information, energy and materials. Figure 6 shows the sum of each score (score ranging from 0, 1) after evaluating the presence or absence of interface Criteria, according to the definition of Sharman.

Figure 7 shows the results of DSM Clustering Analysis which was performed by using aforesaid sheet.



	종합제어장치	자동열차제어장치	자동열차운전장치	운전실 설비	집전기	충전기	배터리	정보 안내 장치	HVAC	대차 프레임	견인장치	공기압축기	연결장치	현가장치	인버터	추진모터	브레이크	휠	동력전달장치	윤축
종합제어장치	0	1	1	1	1	1	1	1	0	0	0	1	0	1	2	1	1	0	0	0
자동열차제어장치	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
자동열차운전장치	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
운전실 설비	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
집전기	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
충전기	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
배터리	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
정보 안내 장치	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
HVAC	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
대차 프레임	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1	1	0	1	0
견인장치	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
공기압축기	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
연결장치	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
현가장치	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
인버터	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
추진모터	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0
브레이크	1	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
휠	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2
동력전달장치	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	1
윤축	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0

Fig. 6: Sum of each score after evaluate



클러스터링 결과(Shamman)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
종합제어장치	0	1	1	1	1	1	1	1		2	1			1		1	1			
자동열차제어장치	1	0	1	1						1										
자동열차운전장치	1	1	0	1						1										
운전실 설비	1	1	1	0						1										
집전기					0					1										
충전기	1					0	1			1										
배터리						2	0													
정보 안내 장치			1	1				0		1										
HVAC	1			1					0	1										
인버터	1	1	1		1					0	2									
추진모터										2	0	1								
대차 프레임											1	0	1	1	1	1	1		1	
견인장치												1	0							
공기압축기	1											1		0						
연결장치												1		1	0					
현가장치	1											1		1		0				
브레이크	1	1										1		1			0			
휠																	1	0	1	2
동력전달장치											1	1						1	0	1
윤축																		2	1	0

Fig. 7: Result of Sharman clustering

It was found that 46.18% improvement was achieved when the modularization scores were calculated based on the results as derived:

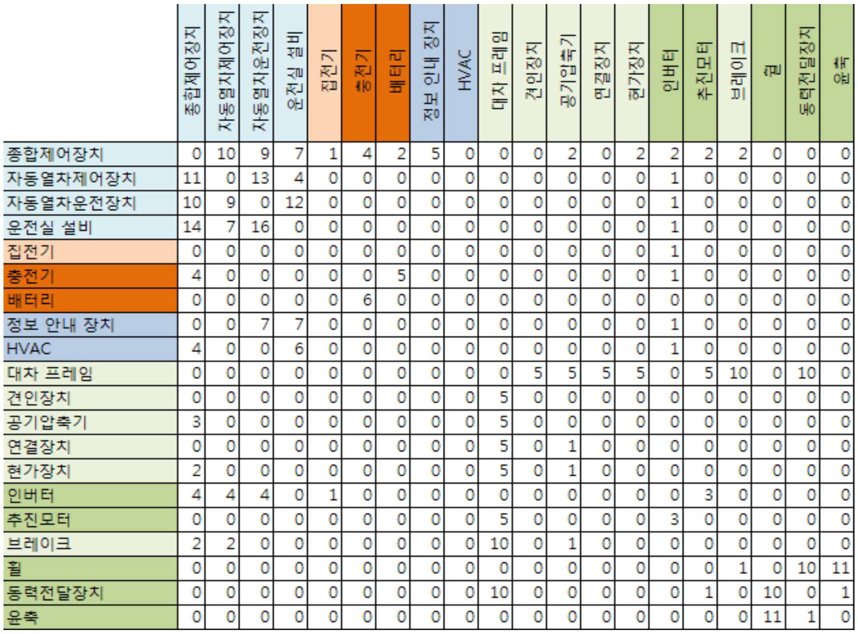
- Before the Clustering Analysis: 1,520
- After Clustering Analysis: 818
- Modular ratio: 46.18%

Application of the proposed information quantity evaluation method: Under the proposed evaluation method, cohesion information quantity of each interface is calculated by using the formula (1) after entering the quantity of interface requirements in the sheet (Fig. 8).

Figure 9 was derived by multiplying 100 by the result value for the sake of computational convenience for information quantity that had been derived.

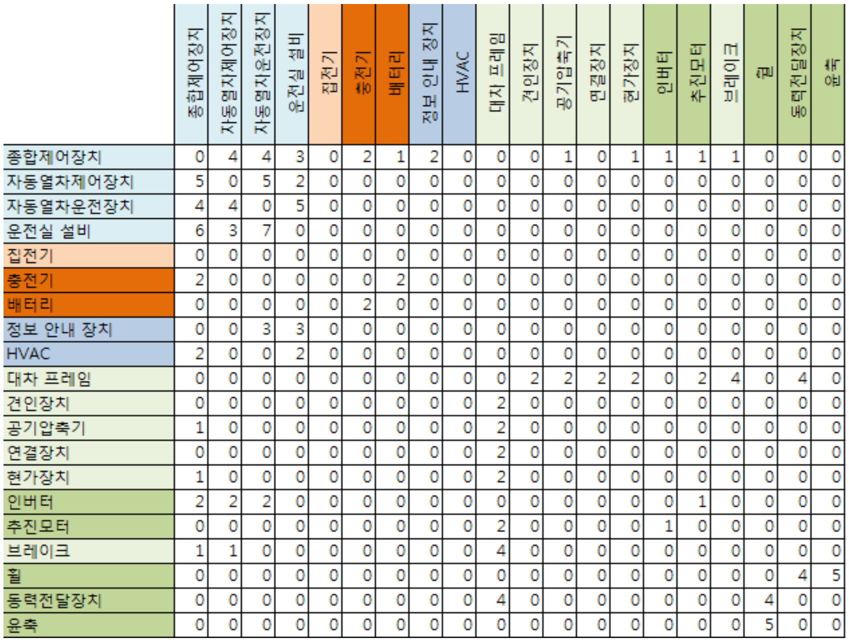
The results of DSM Clustering Analysis based on aforesaid sheet are presented in Fig. 10.

It was found that 53.39% improvement was achieved when the modularization scores were calculated based on the results as derived above:



	종합제어장치	자동열차제어장치	자동열차운전장치	운전실 설비	집전기	충전기	배터리	정보 안내 장치	HVAC	대차 프레임	견인장치	공기압축기	연결장치	현가장치	인버터	추진모터	브레이크	휠	동력전달장치	윤축
종합제어장치	0	10	9	7	1	4	2	5	0	0	0	2	0	2	2	2	2	0	0	0
자동열차제어장치	11	0	13	4	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
자동열차운전장치	10	9	0	12	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
운전실 설비	14	7	16	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
집전기	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
충전기	4	0	0	0	0	0	5	0	0	0	0	0	0	0	1	0	0	0	0	0
배터리	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
정보 안내 장치	0	0	7	7	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
HVAC	4	0	0	6	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
대차 프레임	0	0	0	0	0	0	0	0	0	0	5	5	5	5	0	5	10	0	10	0
견인장치	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
공기압축기	3	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
연결장치	0	0	0	0	0	0	0	0	0	5	0	1	0	0	0	0	0	0	0	0
현가장치	2	0	0	0	0	0	0	0	0	5	0	1	0	0	0	0	0	0	0	0
인버터	4	4	4	0	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
추진모터	0	0	0	0	0	0	0	0	0	5	0	0	0	0	3	0	0	0	0	0
브레이크	2	2	0	0	0	0	0	0	0	10	0	1	0	0	0	0	0	0	0	0
휠	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	10	11
동력전달장치	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	1	0	10	0	1
윤축	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	1	0

Fig. 8: Entering the quantity of interface requirements



	종합제어장치	자동열차제어장치	자동열차운전장치	운전실 설비	집전기	충전기	배터리	정보 안내 장치	HVAC	대차 프레임	견인장치	공기압축기	연결장치	현가장치	인버터	추진모터	브레이크	휠	동력전달장치	윤축
종합제어장치	0	4	4	3	0	2	1	2	0	0	0	1	0	1	1	1	1	0	0	0
자동열차제어장치	5	0	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
자동열차운전장치	4	4	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
운전실 설비	6	3	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
집전기	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
충전기	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
배터리	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
정보 안내 장치	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HVAC	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
대차 프레임	0	0	0	0	0	0	0	0	0	0	2	2	2	2	0	2	4	0	4	0
견인장치	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
공기압축기	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
연결장치	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
현가장치	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
인버터	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
추진모터	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0
브레이크	1	1	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
휠	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	5
동력전달장치	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	4	0	0
윤축	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0

Fig. 9: Multiplying 100 by the result value

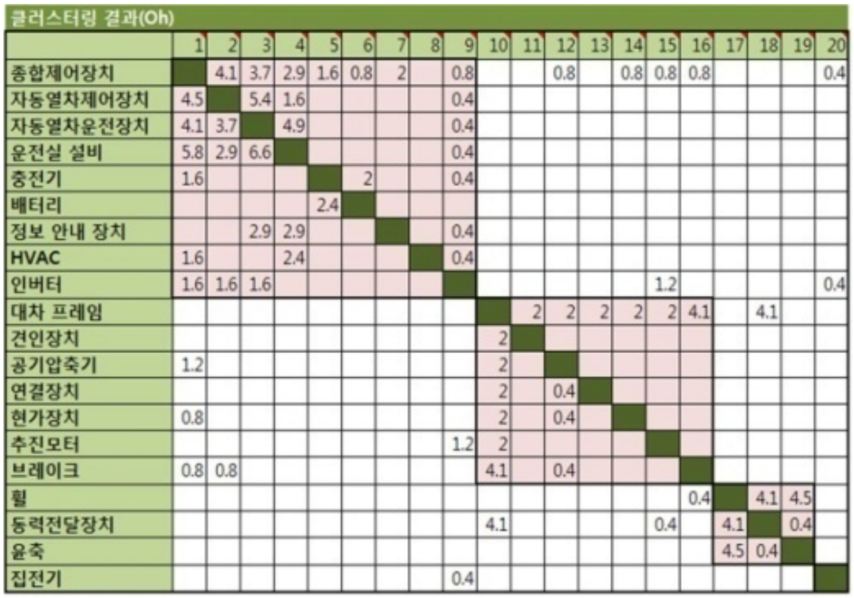
- Before the Clustering Analysis: 2,918
- After Clustering Analysis: 1,360
- Modular ratio: 53.39%

Comparative analysis of results: Figure 11 presents the comparison between the results of interface cohesion scores derived by using the proposed method and other results.

The results obtained through method proposed by the author were found to show 1.77% improvement compared to those obtained through Pimmler's method and 7.21% modularization improvement compared to those obtained through Sharman's method.

DISCUSSION

The results of clustering analysis, which were obtained through the interface cohesion evaluation method proposed in this study, showed a difference of up to 7.21% compared to the clustering analytical



클러스터링 결과(Oh)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
종합제어장치	■	4.1	3.7	2.9	1.6	0.8	2		0.8			0.8		0.8	0.8	0.8				0.4
자동열차제어장치	4.5	■	5.4	1.6					0.4											
자동열차운전장치	4.1	3.7	■	4.9					0.4											
운전실 설비	5.8	2.9	6.6	■					0.4											
충전기	1.6				■	2			0.4											
배터리					2.4	■														
정보 안내 장치			2.9	2.9			■		0.4											
HVAC	1.6			2.4				■	0.4											
인버터	1.6	1.6	1.6						■						1.2					0.4
대차 프레임										■	2	2	2	2	2	4.1		4.1		
견인장치										2	■									
공기압축기	1.2									2		■								
연결장치										2		0.4	■							
현가장치	0.8									2		0.4		■						
추진모터									1.2	2					■					
브레이크	0.8	0.8								4.1		0.4				■				
휠																0.4	■	4.1	4.5	
동력전달장치										4.1					0.4		4.1	■	0.4	
윤축																	4.5	0.4	■	
집전기									0.4											■

Fig. 10: Result of DSM clustering analysis

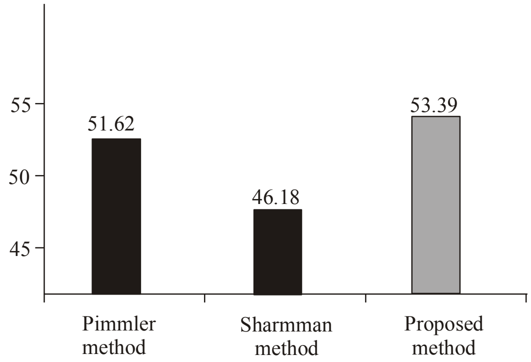


Fig. 11: Comparison between the results

results obtained through existing evaluation methods. These results have the implication as explained below.

In the first place, Sharman's method enabled easy evaluation of interface and therefore required very small amount of time to be put into analysis, but had slightly lower reliability of results compared to Pimmler's method. Pimmler's method enabled relatively higher degree of modularization improvement compared to Sharman's method, but required a considerable amount of time and effort. The method proposed by the author was found to bring 1.77% improvement compared to Pimmler's method, but has difficulty in generalizing such level of modularization improvement as significant based on the figure. However, the method proposed by the author has the advantage that it can drastically reduce the time for modularization analysis because this method uses as source document the ICD which is the conventional outcome of functional architecture analysis instead of separate evaluation performed by expert. In other words, aforesaid results suggest that the level of reliability was found to be similar to that of Pimmler's method without need for separate evaluation process.

CONCLUSION

This study presents the method for evaluating interface cohesion among elements necessary for carrying out DSM Clustering. Pimmler's method and Sharman's method are the most commonly used methods for evaluation.

Pimmler's method produces results with high reliability and therefore was used in many studies (Cabrera *et al*., 2014; Chakrabarti *et al*., 2011; Fixson and Park, 2008; Li and Mirhosseini, 2012; Pil and Cohen, 2006; Stone *et al*., 2000; Yassine and Braha, 2003). However, Pimmler's method requires a considerable time and effort to be put into evaluation process and furthermore requires the involvement of many evaluators if high reliability is to be achieved.

Sharman' method is very simple, compared to Pimmler's method and therefore can reduce loss of time and has been applied to many studies (Börjesson, 2012; Baldwin and Clark, 2002; Borjesson and Hölttä-Otto, 2012, 2014; Ko, 2013; Oh and Park, 2015; Yu *et al*., 2003, 2007). However, Sharman' method is not appropriate to apply, given that this method does not produce results reliable enough for analysis of complex system.

In this study, we introduced Information Theory of Shannon to resolve problems described above. Mathematical formulas were proposed for deriving entropy value of each interface based on interface requirements identifiable through ICD. For verification, Pimmler's method, Sharman's method and proposed method were applied to the analysis of interface for some components of railway system. Clustering analysis was performed based on respective results. The outcomes of analysis showed that the proposed method produced the modularization result which was 7.21% higher compared to the results achieved by Sharman's method and generated a level of modulation results similar to the level achieved by Pimmler's method. The proposed method guarantees high efficiency as it obviates the need for separate evaluation process involving experts as required by Pimmler's method.

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