

An Empirical Study on Improving the Manufacturing Informatization Index System of China

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Abstract

The manufacturing informatization index system (MIIS) is an indispensable tool to measure the informatization level of Chinese manufacturing industry and evaluate the implementation effect of the manufacturing informatization engineering (MIE) conducted by the government of China. Thus far, the constructs of MIIS has not been validated. This study fills this void by employing structural equation modeling (SEM) to test the MIIS model. The samples in this study come from the standard database of Chinese manufacturing informatization established by the data survey of MIE during the "Tenth Five-Year Plan" period, including 12896 enterprises samples from 11 manufacturing industries and 3472 support samples from 29 provinces of China. Based on the results of SEM analysis, some indexes of MIIS are adjusted and an improved MIIS is got at last. This empirical study proves that combining SEM technology and standard data resources would be an ideal method to improve MIIS.

1. Introduction

The manufacturing informatization engineering (MIE), which is conducted by the government of China, is a systems engineering for improving the competition ability of the Chinese manufacturing enterprises by informatization means. Measuring the level of domestic manufacturing informatization, the manufacturing informatization index system (MIIS) is an indispensable tool to evaluate the implementation effect of MIE. During the "Tenth Five-Year Plan" period, basing on the MIIS proposed by literature [1], the data survey of MIE was implemented in the scope of 29 provinces and 46 main cities of China annually.

As a result, more than 16000 samples were successfully collected. Basing on these actual data, the manufacturing informatization index (MII) was calculated quantitatively and issued continuously, which generally explained the development of MIE in the "Tenth Five-Year Plan" period and would effectively support the top design of MIE in the "Eleventh Five-Year Plan" period.

Although the MIIS had been practically used in the "Tenth Five-Year Plan" period, it is still not perfect. The major problem is the theoretical constructs of MIIS lack a valid measurement. Actually, the existing MIIS is designed mainly in subjective view and basically represents the will of the investigator. However, the validity of the index choosing of MIIS has not been confirmed. Whether the constructs authentically reflects the relationships between those key factors in the manufacturing informatization process of China, it is still a question. An excuse for this negligence is that the existing MIIS was the first edition and built five year ago, when there was no objective support for validation analysis. But now, since we already have the standard database of Chinese manufacturing informatization built by the data survey of MIE in the past five years, the validating work for MIIS based on data resources should be on the way. Obviously, these efforts will improve MIIS to be more exact and effective.

Based on the standard database of manufacturing informatization, this paper proposed a method using structural equation modeling (SEM) to improve the MIIS. SEM is a confirmatory data analysis technique that is very popular in recent years. Because of its advantages in testing correlations and causality between multiple variables, it is widely used in empirical studies of many fields. In this study, SEM is employed to validate the index choosing of MIIS and support the improving of its constructs. This method

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had already been used in the current modification work of MIIS and proved feasible and effective.

The organization of this paper is as follows: in section 2, the status quo of MIIS is introduced. Then, the research methodology is proposed in section 3. In section 4, the process of the empirical study is illustrated, including sample collection, model construction, data analysis and final results. At last, discussion is made on issues in the research and conclusion about the study ends the paper.

2. Status quo of MIIS

The MIIS is composed of two parts: Manufacturing Informatization Enterprise Index System (MIEIS) and Manufacturing Informatization Support Index System (MISIS). The former focuses on the interior informatization status of kinds of manufacturing enterprises, such as leadership, infrastructure, benefits and so on. The latter focuses on the exterior support for the informatization construction of manufacturing enterprises, such as policy, technology and service. Both MIEIS and MISIS have a two-level structure where the first level is called index and the second one is called sub-index. Every index is measured by one or multiple sub-indexes. Based on the basic purpose of evaluating implementation effect of MIE and the situation of China, the index and sub-index of MIIS is chosen considering the suggestions from government, experts, and other concerned participants.

In existing MIEIS, we evaluate the informatization level of manufacturing enterprise from six aspects: informatization leadership (informatization leadership), infrastructure conditions (informatization investment, computer quality, network capability and rate of connected computer), application status (management support status, e-commerce and supply chain status, R&D status and operation flow status), human resources (general quality, informatization skill and e-learning), informatization safety (investment, failure time and solution), informatization benefits (management support benefits, e-commerce and supply chain benefits, R&D benefits and operation flow benefits). The structure of MIEIS is shown as Fig. 1.

In existing MISIS, we evaluate the support for the informatization construction of manufacturing enterprises from three aspects: policy support (government investment, number of supported projects, influence power of demonstration enterprises, benefits of supported homemade software), technology support (popularity of homemade software, price of key technology, ability of absorbing advanced technology, standardization level of technology and number of software with independent intellectual

property rights), service support (service incoming, service capability and number of practitioner). The structure of MISIS is shown as Fig. 2.

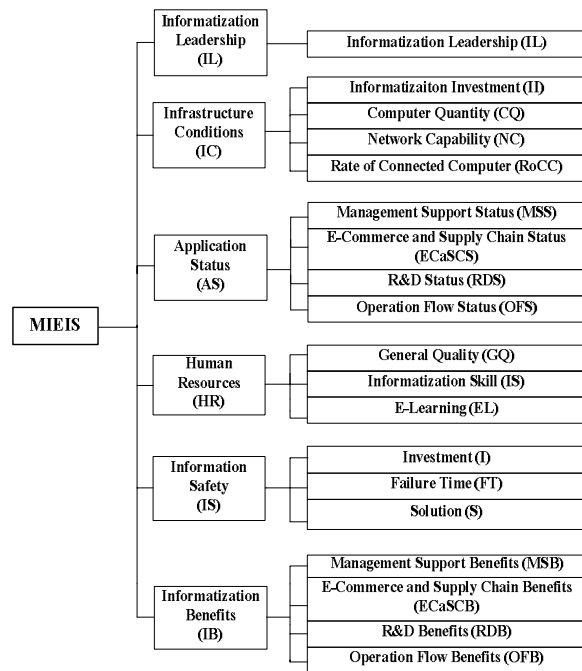


Figure 1. The structure of MIEIS

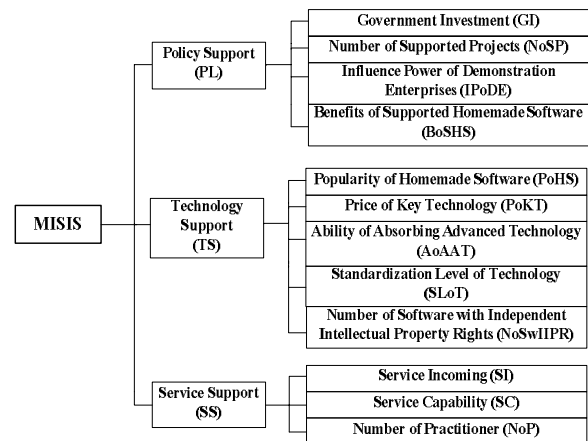


Figure 2. The structure of MISIS

3. Methodology

3.1. Method

Structural equation modeling (SEM) is an analysis technique for multiple variables and is widely used for testing the research model in many fields such as education, psychology and management and so on. Its analysis capability about measuring error and dealing with structural equation provides a useful tool for

testing correlations, causes and effects. SEM is composed of two parts, i.e. measurement model and structure model. The measurement model tests the correlations between indirect latent variables and variables that can be tested directly while the structure model gives the causality of exogenous variables and endogenous variables [2]. Thus, the modeling also has two steps: validating the measurement model and refining the structural model. The former is accomplished primarily through confirmatory factor analysis, while the latter is accomplished primarily through path analysis with latent variables. Each variable in the model is conceptualized as a latent one, measured by multiple indicators.

The reasons we choose SEM as the tool to improving MIIS are based on three considerations: Firstly, we have the standard database of manufacturing informatization, which is the powerful support for SEM analysis. Secondly, the MIIS was designed subjectively and the constructs need confirmatory analysis against data, which is the characteristic of SEM. Thirdly, the improving of MIIS is mainly implemented by adjusting indexes according to the correlations among them, which is just satisfied by the confirmatory factor analysis of SEM.

In this study, the improving of MIIS basically means the adjusting of the constructs. The correlations between indexes (indirect latent variable) and sub-indexes (direct measurable variable) are the basis to adjust the constructs. So, either MIEIS or MISIS can be creatively seen as a measurement model and the technique of SEM certainly comes in handy. The model testing process of SEM can be employed to validate the constructs of MIIS and the confirmatory factor analysis of SEM is just the tool we need. Thus, we can use confirmatory factor analysis to validate the correctness of index designing and the rationality of MIIS structure, with the analysis results guiding the deletion and displacement of indexes. In this way, the improving of MIIS based on data can be implemented.

3.2. Steps

Because MIIS has two independent parts (MIEIS and MISIS), the improving of the whole MIIS must be implemented respectively. Even though, there are no methodological differences in these two improving processes and either MIEIS or MISIS can be improved firstly. As a whole, the basic steps of the improving process for MIIS mainly include:

- 1) Pick out the enterprise (or support) data from the standard database.
- 2) Implement SEM analysis using the chosen data and the existing MIEIS (or MISIS).

3) Adjust the MIEIS (or MISIS) according to the analysis results.

4) Implement SEM analysis using the same data and the adjusted MIEIS (or MISIS).

5) Repeat step 3) and step 4) until the analysis result is satisfied.

6) Obtain the improved MIEIS (or MISIS).

7) Repeat step 1) to step 6) to obtain the improved MISIS (or MIEIS).

8) Obtain the final improved MIIS.

The whole process is shown as Fig.3.

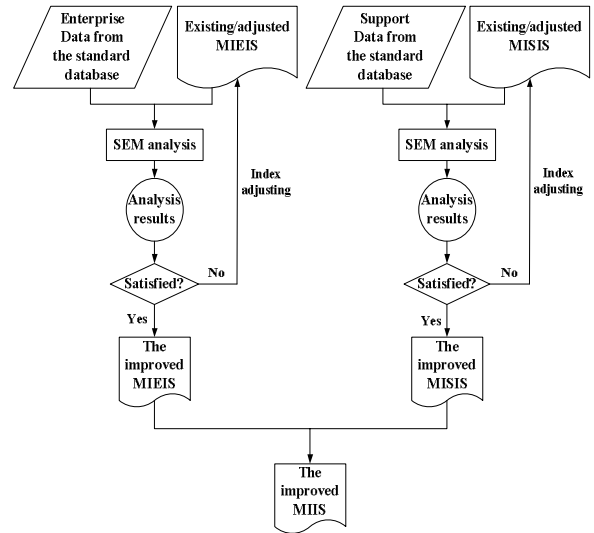


Figure 3. The process of improving MIIS

4. Empirical study

4.1. Sample and data collection

The original data of this paper come from the standard database of Chinese manufacturing informatization we have. This database was established by the data survey of MIE during the “Tenth Five-Year Plan” period, including 12896 enterprises samples from 11 manufacturing industries and 3472 support samples from 29 provinces of China. Now, it is one of the most authoritative and important databases in the informatization field of China.

The data survey was implemented by answering questionnaires (including enterprise data questionnaire and support data questionnaire) via internet <<http://www.mie-idc.cn>>. According to the MIEIS, the enterprise data questionnaire is made up of by 66 questions belonging to six parts: basic information (14 questions), finance and investment (14 questions), human resources and leadership (5 questions), infrastructure conditions (5 questions), application status (14 questions), and requirement survey (14

questions). According to the MISIS, the support data questionnaire is made up of by 20 questions belonging to three parts, i.e. policy (11 questions), technology (6 questions) and service (3 questions). Actually, the values of sub-indexes are calculated according to the answers of these questions and further figure out the values of the indexes. All the questionnaires can be downloaded from <http://www.mie-idc.cn>.

The data survey is organized by the local Science and Technology Office and supported by all participators. The enterprise data questionnaire's answerers are various manufacturing enterprises while the support data questionnaire's answerers are local governments, agency organizations and software associations.

4.2. Model and variables

In this study, the two parts of MIIS are just seen as two measurement models: MIEIS model (as Fig.1 shows) and MISIS model (as Fig.2 shows). Apparently, variables of these two models are the indexes and sub-indexes. The index, i.e. the indirect latent variable, can not be measured directly and every index is composed by one or more sub-indexes. The sub-index, i.e. the direct measurable variable or observable indicator, can be calculated directly from the sample data.

4.3. Data analysis

Because MIEIS model and MISIS model are independent, the data analysis of them are implemented respectively. Considering the paper space limitation, here we only take data analysis of MIEIS as an example to illustrate the general process. The solution to MISIS is similar. The enterprise data using for MIEIS testing are 9689 samples from 8 important manufacturing industries. The basic information of these samples is shown in Table 1—Table 3.

Table 1. Enterprise by industry type

Code	Industry type	Frequency	Percent
C0	Food and drinks	759	7.83%
C1	Spinning and garment	879	9.07%
C2	Wood and furniture	360	3.71%
C3	Paper making and printing	427	4.41%
C4	Oil, chemistry and plastic	752	7.76%
C5	Electronics	2479	25.59%
C6	Metal and nonmetal	868	8.96%
C7	Mechanical and equipment	3165	32.67%
	Total	9689	100.00%

Table 2. Enterprise by production type

Production type	Frequency	Percent
Discrete	3920	40.46%
Consecutive	3035	31.32%
Mixed	2734	28.22%
Total	9689	100.00%

Table 3. Enterprise by ownership

Ownership type	Frequency	Percent
State-owned	3520	36.33%
Foreign-owned	1278	13.19%
Private	2357	24.33%
Joint venture	2534	26.15%
Total	9689	100.00%

LISREL 8.14 was used to conduct the data analysis. The assumptions of multivariate analysis—normality, linearity, and homoscedasticity—were tested for the variables used in the model. Analysis of the research model for the assumptions of the multivariate model indicated no statistically significant violations. Principally, the constructs validity of MIEIS model was assessed.

The reliability (including Individual Item Reliability and Composite Reliability), validity (including Convergent Validity and Discriminant Validity), factor loading and goodness of fit index (GoFI) are the main measurement parameters we concerned. The analysis results are listed in Table 4—Table 6. As Table 4 and Table 5 show, nearly all the variables have the satisfactory reliability and validity. Moreover, the goodness-of-fit indexes in Table 6 reveal a good fit of the model to the data. But, from Table 5, we find that some measurement parameters of RoCC and EL such as “Individual Item Reliability”, “t-values” and “Standardized Factor Loading” get very low values. According to the results of model testing against data, we are convinced that the MIEIS model is not bad but these two variables need to be reconsidered. In other words, the results reveal that these two sub-indexes are not appropriate to explain their upper index.

Table 4. Testing discriminant validity

Latent Variables	IC	AS	HR	IS	IB
IL	13.4231***	10.2341**	18.2341***	9.2341**	11.2312**
IC		16.3421***	9.5322**	8.7524*	17.4923***
AS			17.4583***	8.5242*	6.3461*
HR				10.2346**	9.5789**
IS					7.5323*

*p<0.05, ** p<0.01, *** p<0.001

Table 5. Validity of existing MIEIS model

Latent Variables (Index)	Measurable Variables (Sub-index)	Individual Item Reliability (Cronbach's alpha)	Composite Reliability	Convergent Validity (t-values)	Convergent Validity (Standardized Factor Loading)
IL	IL	0.9135	0.9135	11.4567***	0.9341
IC	II	0.8657	0.8737	15.4567***	0.8239
	CQ	0.7958		18.1567***	0.7945
	NC	0.9423		19.1238***	0.9016
	RoCC	0.7594		1.2566	0.2237
AS	MSS	0.8670	0.9076	15.3587***	0.8823
	ECaSCS	0.7856		10.3476**	0.9345
	RDS	0.9833		19.2563***	0.9291
	OFS	0.8418		17.3437***	0.9323
HR	GQ	0.8874	0.8871	11.3452**	0.9004
	IS	0.9561		16.3498***	0.8649
	EL	0.2412		1.1845	0.1945
IS	I	0.9347	0.9226	14.2311***	0.9578
	FT	0.9712		16.3829***	0.8429
	S	0.8639		19.4762***	0.9497
IB	MSB	0.9156	0.8923	17.4285***	0.8317
	ECaSCB	0.8664		18.6529***	0.8538
	RDB	0.9011		15.4269***	0.9431
	OFB	0.8755		19.3417***	0.9127

*p<0.05, ** p<0.01, *** p<0.001

Table 6. Testing results of existing MIEIS model

GoFI	df	χ^2	GFI	RMSEA	NNFI	CFI
Value	174	315	0.92	0.03	0.90	0.91

Table 7. Testing results of improved MIEIS model

GoFI	df	χ^2	GFI	RMSEA	NNFI	CFI
Value	137	243	0.95	0.03	0.94	0.96

From the analysis results, we consider there maybe something wrong or inappropriate in index designing. The sub-index “Rate of Connected Computer” represents the condition of computers connecting via network and certainly an important factor of infrastructure conditions. But the problem is that it has the analogous and repetitive meaning with “Computer Quantity” and “Network Capability”. As CQ and NC are more exact and popular in evaluating the level of infrastructure conditions, RoCC seems redundant. The other sub-index “E-Learning” represents the condition of employee learning via informatization means, which focuses on the employee learning channel. The problem is that its upper index “Human Resources” focuses on the support of talents for the informatization construction, which means the key should be the quality of the person not the learning method of the person. So, EL seems unsuitable for explaining HR. Moreover, we seek for suggestions from experts and some enterprise participators, whose opinions validate our explanation.

Considering the suggestion both from objective data and the subjective explanation, we decide to delete these two sub-indexes. Thus, the first adjusting of MIEIS is accomplished. Then, according to the

improving process, we continue to employ the adjusted model and the same data to implement SEM analysis. As a result, all the measurement parameters this time are remarkable and the goodness-of-fit indexes in Table 7 reveal a better fit of the model to the data. This is a satisfying result we can accept.

4.4. Results

As the second analysis result validates the rationality of our adjusting and is really a satisfying one in our opinions, the improving process of MIEIS is finished and the final improved MIEIS is shown as Fig.4.

In the same way, the improved MISIS is obtained with the support of the standard database. Actually, the improved MISIS is just the existing one as there is no need to do any modification according to the data analysis results. Though, it is still seen as an improved one because of having been validated. Both the improved MIEIS and the improved MISIS make up of the newly whole MIIS together, which will be used in the “Eleventh Five-Year Plan” period.

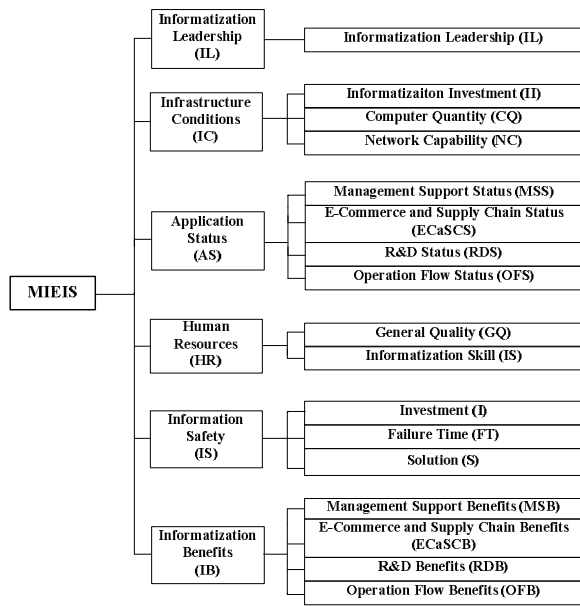


Figure 4. The improved MIEIS

5. Discussion and conclusion

MIIS is an indispensable tool to measure the informatization level of Chinese manufacturing industry and evaluate the implementation effect of MIE. So, the validity and rationality of MIIS constructs is very important. This paper gives a first insight into this issue and attempts to solve it from a new point of view. Based on the data resources, the SEM are employed to validate the index choosing, which explores a new path to improve MIIS. However, the task of MIIS improving is not only limited to index modification and will change with the development of manufacturing informatization. Some improving works should be done in further research, such as index weight distributing optimization and reification according to different manufacturing industry types.

In this paper, the constructs of MIIS is validated through SEM and an improved MIIS is finally proposed. This improved MIIS will be sequentially tested by the data from the future data survey of MIE and continually improved.

Undoubtedly, SEM is a powerful tool to validate the constructs of hypothetical model. Thus, the empirical study combining SEM technology and standard data resources would be an ideal method to improve MIIS.

6. References

[1] The leading and coordinative team of manufacturing informatization engineering, *The Training Handbook of Data Survey of MIE*, 2003.

[2] Yanjiang Cheng, Dan Wang, Lang Xie, "Influencing Factors of Continuous Improvements and Tendency of Change," *2006 IEEE International Conference on Management of Innovation and Technology*, 2006, pp.181-185.

[3] Tianjin Ding Cheng Contemporary Integrated Manufacturing Technology Engineering co., Ltd, *Declaration of Manufacturing Informatization Performance Evaluation System Establishment*, 2006.

[4] Wei Guo, Mingyan Hu, Rong Wang, Qingxing Li, "Research on the Interactive Model of Regional Informatization Market System," *Computer Integrated Manufacturing System*, vol. 10, Special Magazine, December 2004, pp.172-176.

[5] Rong Wang, "Research and Application on System of Manufacturing Informatization Exponent", *Dissertation*, Tianjin University, Tianjin, 2003.

[6] K. G. Jöreskog and D. Sörbom, *LISREL 8*, Scientific Software International, Chicago, IL, 1993.

[7] K. G. Jöreskog and D. Sörbom, *LISREL 8: Structural Equation Modeling with the SIMPLIS Command Language*, Lawrence Erlbaum Associates Publishers: Hillsdale, NJ, 1993.

[8] E. K. Kelloway, "Structural Equation Modeling in Perspective," *J. Org. Behavior*, vol. 16, 1995, pp. 215-224.

[9] B. W. Keats, "The Vertical Construct Validity of Business Economic Performance Measures," *J. Appl. Behav. Sci.*, vol. 24, 1988, pp. 151-160.

[10] Hale Kaynak, "The Relationship Between Just-in-Time Purchasing Techniques and Firm Performance", *IEEE Transactions on Engineering Management*, vol. 49, no. 3, August 2002, pp. 205-217.