# Product Innovation Factor Analyses in Korean Manufacturing Enterprises

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*Abstract*--**Korea economy has been rapidly developed through manufacturing industry since 1960s. Current business environments is very complex and its uncertainty is also growing rapidly. Many manufacturing firms in Korea are trying to deploy an innovative product, but they are facing a difficulties for product innovation because of various complexity such as environment, organization, and customer. In this context, the purpose of this paper is to identify the product innovation factors in Korea manufacturing industry and to analyze a driving power and dependence power among them. And then, it finally shows findings and implications for a management point of product innovation variables reflecting industrial characteristics of three major manufacturing industry in Korea: chemicals, electronics/optical product and motor vehicles. This research uses interpretive structural modeling (ISM) and Cross-impact matrix multiplication applied to classification (MICMAC) methodologies, which is derived from product innovation data of Korea Innovation Survey (KIS).**

## I. INTRODUCTION

Since global business environment is rapidly changing and under high uncertainty, many firms are trying to have an innovation on product and services for predominance in competition. Korea has been focusing on manufacturing industry and is also trying to launch an innovative product coping with environment. For innovative product in firms, it is essential part to identify a relationship, hierarchies and enablers of product innovation and it should be considered in terms of industry characteristics as well.

In this paper the main focus is to identify product innovation factors as one of key success factor in Korean manufacturing industry. We used Korea Innovation Survey (KIS) data and applied structural analysis methodologies to figuring it out.

This paper is organized as follows: Section 2 presents a review of the previous literature about product innovation and the research methodologies. Section 3 presents data, basic statistics, and product innovation variables determined. Section 4 gives the methodology deployed, the estimation results and Section 5 shows their meaning and the key findings through the discussion. Finally, section 6 provides the conclusion.

## II. BACKGROUND AND RESEARCH QUESTIONS

### *A. Literature Review*

1) Product Innovation

According to the OECD, product innovation is defined as "the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses." Also it includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics [8]. In particular, it is an important innovation type for manufacturing firms with process innovation, marketing innovation and organization innovation.

Product innovation can be defined as the development of new products, changes in design of established products, or use of new materials or components in the manufacture of established products. It means product innovation can be divided into two categories: development of new products, and improvement of existing products. One example of the new product innovation is digital camera or smartphone with film camera function. ABS break system and GPS navigation in car are proper example of improvement of existing products. But, technology performance improvement and similar design change are not the product innovation.

2) MICMAC

Cross-impact matrix multiplication applied to classification (MICMAC) developed by Godet [4] have been used to classify variables. This method is based on the reachability matrix using focused group interview. The main objective of MICMAC is to classify the variables according to their driving power and dependence power. And they are plotted a graph with dependence power on x-axis and driving power on y-axis. As explained below, the variables can be classified in four categories, namely: autonomous, dependent, linkage and independent. These clusters provide fundamental understanding of related variables.

- Cluster I: Weak driving power and weak dependence power factors. These factors are *autonomous* or *excluded* factors.
- Cluster II: Weak driving power and strong dependence power factors, a group of so-called *dependent* or *dominated* factors.
- Cluster III: Strong driving power and strong dependence power factors. These *linkage* or *relay* factors impact others.
- Cluster IV: Strong driving power and weak dependence power factors. They are called *independent* or *dominant* factors. These variables in this cluster are the most important variables as they strongly influence others. Therefore are called *driving* variables

3) ISM

Interpretive Structural Modeling (ISM) is proposed by Warfield [14] and has been developed by various authors such as Sage [10], Warfield [13], Moore [7], etc. It is an effective methodology for dealing with complex issues and helps in understanding the structure of a complex system as its visualization. ISM can be applied by following certain steps. They are listed as below:

- Step 1. Identify variables.
- Step 2. Generate a reachability matrix.
- Step 3. Analyze the MICMAC.
- Step 4. Partition into reachability sub-matrix.
- Step 5. Form lower triangular/conical matrix.
- Step 6. Develop the hierarchical diagraph.

This method has been widely applied to various issues as shown Table 1. Sagheer *et al.* [11] identified and analyzed critical factors and elements affecting India food industry using by MICMAC method. Sahoo *et al.* [12] identified the relationship, hierarchies and enablers of strategic technology management using by ISM and MICMAC. Pfohl *et al.* [9] showed that ISM is useful methodology to structure SCM risk. Chander *et al.* [1] applied ISM and MICMAC to identify and classify the key factors of information security management. Debata *et al.* [2] applied ISM and Fuzzy MICMAC analysis to identify a medical tourism enablers in India. Diabat *et al.* [3] analyzing the interaction among the key barriers in third-party logistics (TPL) in manufacturing industries. Gorane *et al.* [5] identified 24 key SCMEs and developing an integrated model using ISM and the fuzzy MICMAC approach.

*B. Research Questions*

As we mentioned earlier, the objective of this paper is for figuring out a relationship among product innovation variables in Korea manufacturing industry, focusing on chemicals, electronics, and motor vehicles sectors. Then we analyze its characteristics and show key findings on it. Our research questions can be summarized as below:

- What are mutual relationships and hierarchies among product innovation variables in Korea manufacturing industry?
- What distinction does exist between those inter-relationships depends on manufacturing industry?

## III. RESEARCH MODEL AND DATA

*A. Research Model*

Fig. 1 shows our research model in this paper, which can be divided into three stages. We modified traditional ISM procedure and Kannan *et al.* [6]. First stage is extracting product innovation variables from KIS data and building relation matrix as basic analysis. To do so, we had focused-interview with four industry experts. Secondly, we derived cluster and a relation hierarchy among product innovation variables, which was done through MICMAC and ISM methodology. In addition, we conducted more advanced analysis through quantitative and qualitative approach. Last stage is checking results of analysis to obtain validation for our model. If model is invalid, we should regenerate a reachability matrix. Otherwise, model is valid, we can derive the key findings and implications.

TABLE 1. COMPILATION OF LITERATURE REVIEW

| Year | Author(s) | Title of Paper | Paper Type/Content |
|---|---|---|---|
| 1976 | Warfield | Implication structures for system interconnection matrices Interpretative | Theory: mathematical explanation and matrices formation |
| 1977 | Sage | Interpretative structural modeling: methodology for large-scale systems | Theory & Application: deploying ISM on complex situations presented by large systems |
| 2009 | Sagheer *et al.* | An application of interpretative structural modeling of the compliance to food standards | Application: identifying and analyze critical factors/elements affecting India food industry using by MICMAC method. |
| 2010 | Sahoo *et al.* | Developing a conceptual framework for strategic technology management using ISM and MICMAC methodology: A case of automotive industry in India | Application: identifying the relationship, hierarchies and enablers of strategic technology management using by ISM and MICMAC. |
| 2011 | Pfohl *et al.* | Interpretive structural modeling of supply chain risks | Application: showing that ISM is useful methodology to structure SCM risk. |
| 2013 | Chander *et al.* | Modeling of information security management parameters in Indian organizations using ISM and MICMAC approach | Application: applying ISM and MICMAC to identify and classify the key factors of information security management. |
| 2013 | Debata *et al.* | Evaluating medical tourism enablers with interpretive structural modeling | Application: applying ISM and Fuzzy MICMAC analysis to identify a medical tourism enablers in India. |
| 2013 | Diabat *et al.* | Benchmarking the interactions among barriers in third-party logistics implementation: An ISM approach | Application: analyzing the interaction among the key barriers in third-party logistics (TPL) in manufacturing industries. |
| 2013 | Gorane *et al.* | Modelling the SCM enablers: an integrated ISM-fuzzy MICMAC approach | Application: identifying 24 key SCMEs and developing an integrated model using ISM and the fuzzy MICMAC approach. |

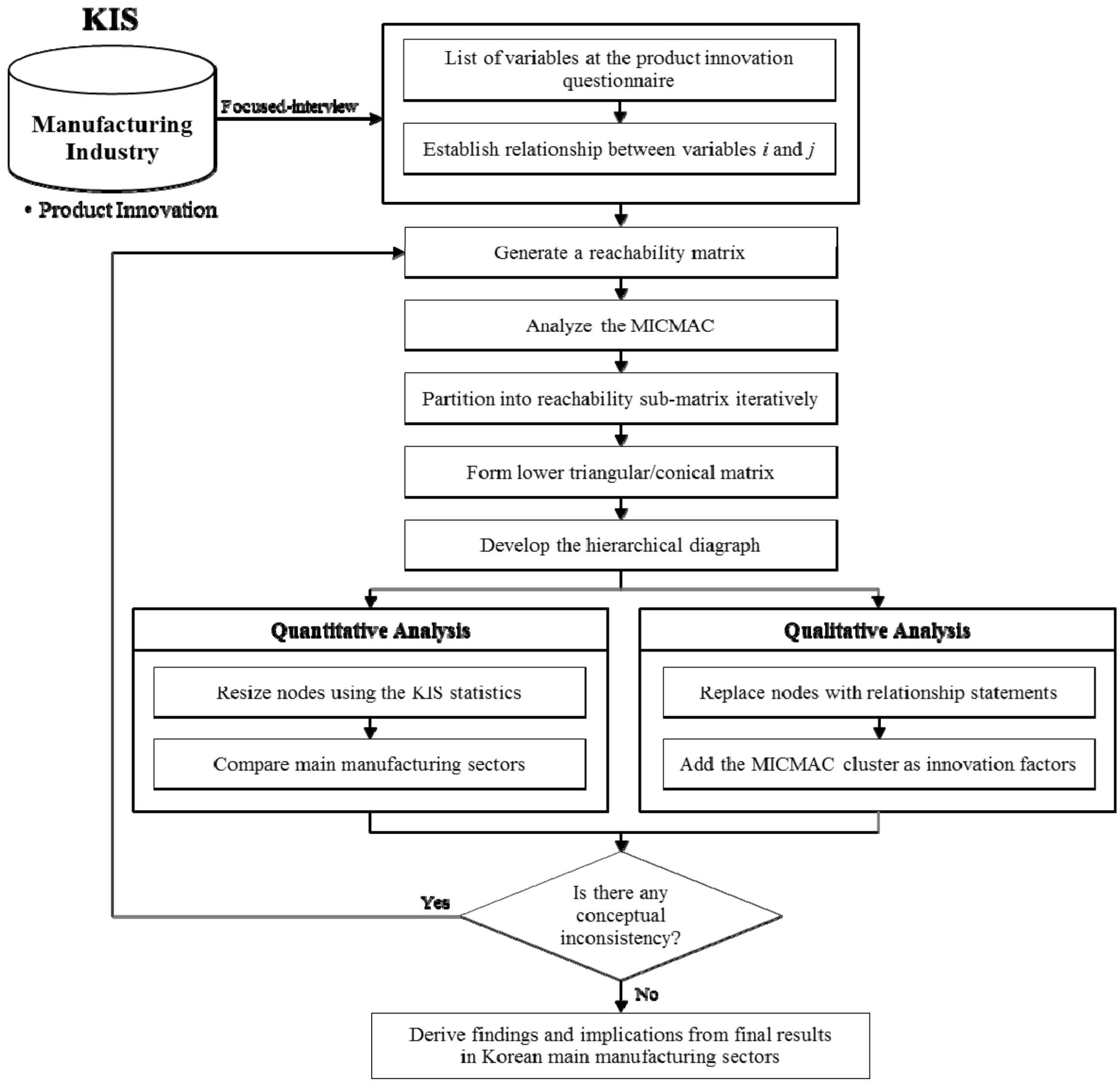


Fig. 1. Research model

TABLE 2. BASIC STATISTICS ABOUT THREE MAIN MANUFACTURING SECTORS IN KIS 2012

| KSIC | Manufacturing Sectors | Population | | Samples | | Product Innovation | | |
|---|---|---|---|---|---|---|---|---|
| | | Number of Firms | Rate of Firms (%) | Number of Firms | Rate of Firms (%) | Rate (%) | Standard Error | CV |
| 20 | Manufacture of chemicals and chemical products | 1,782 | 4.1 | 179 | 4.4 | 31.2 | 3.35 | 10.73 |
| 26 | Manufacture of computer, electronic and optical products | 2,989 | 6.8 | 380 | 9.3 | 16.3 | 1.76 | 10.79 |
| 30 | Manufacture of motor vehicles, trailers and semi-trailers | 2,611 | 6.0 | 315 | 7.7 | 6.7 | 1.32 | 19.58 |
| | Total | 43,810 | 100 | 4,086 | 100 | 100 | - | - |

*B. Data*

We used the result of KIS 2012 conducted by the Science and Technology Policy Institute (STEPI) in Korea. The KIS was approved by the Korea National Statistical Office as Designated Statistics under the Statistics Law and aimed at analyzing the technological innovation of manufacturing firms. It is based on the guidelines of the revised edition of Oslo manual to use definition and methodology. It conducted to grasp an innovation activity of Korean company every 3 years since 1997. The number of responding manufacturing firms is over 4,000. The result of the research is used for developing government policy on innovation. It is published international society and compared with other countries.

In detail, the KIS contents have four parts which are product innovation, process innovation, organization innovation and marketing innovation. This paper focuses on product innovation and three main manufacturing sectors with the KSIC (Korea Standard Industry Code): 20-Manufacture of chemicals and chemical products (excluding pharmaceuticals), 26-Electronics, computers, video, sound and communication equipment manufacturing and 30-Car and trailer manufacturing.

Table 2 shows basic statistics about three main manufacturing sectors in KIS 2012. Total samples size is 4,086 firms, which are about 10% of population. Manufacture of chemicals and chemical products promotes product innovation activity among others.

*C. Variable Measurement*

Table 3 shows product innovation variables from KIS data. We directly extracted ten variables from KIS questions and each variables has its relative characteristics. Those are defined three categories: technology-related, market-related and organization-related. Technology-related contains product technology and process technology.

Each definition and relation grades are showed as Table 3. And we will use variables' notation in short for explanation effectively, i.e. NEWGDS means the first variable.

## IV. ANALYSIS AND RESULTS

*A. Reachability Matrix and MICMAC Analysis*

The reachability matrix is a directed network with binary values. From the reachability matrix, driving power of each variable is calculated by the summation of '1' element in related row. Similarly, dependence power of each variable is calculated by the summation of '1' element in related column. After calculating driving power and dependence power, they are presented as driving power-dependence power matrix with each rank ordered by the summation of values in Table 4. Same rank is existed by the equal summation exactly.

TABLE 4. REACHABILITY MATRIX

| Variables (i/j) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Driving Power | Ranks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.NEWGDS | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 8 | III |
| 2.IMPGDS | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 8 | III |
| 3.NEWMKT | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 9 | I |
| 4.NEWFRM | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 9 | I |
| 5.TRNMKT | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 8 | III |
| 6.TRNFRM | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 8 | III |
| 7.TRNUNG | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 8 | III |
| 8.INHRND | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 7 | VIII |
| 9.EXTRND | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 7 | VIII |
| 10.OUTSRC | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 7 | VIII |
| Dependence Power | 9 | 9 | 10 | 10 | 8 | 8 | 1 | 8 | 8 | 8 | | |
| Ranks | III | III | I | I | V | V | X | V | V | V | | |

We can plot product innovation variables as points in the conventional x-y co-ordinate system. As moving to right of the scale, dependence power increases while that bottom to top indicates a rise in driving power. In the each axis, the driving and dependence power match the relative rank among variables, i.e. the larger power about variable increases, the higher rank is.

TABLE 3. PRODUCT INNOVATION VARIABLES

| No. | Variables | Notation | Technology-related | Market-related | Organization-related |
|---|---|---|---|---|---|
| 1 | The market introduction of new goods | NEWGDS | ◎ | ● | ◎ |
| 2 | The market introduction of significantly improved goods | IMPGDS | ○ | ● | ◎ |
| 3 | The new product innovation in the market | NEWMKT | ● | ● | ● |
| 4 | The only new product innovation in the firm | NEWFRM | ● | ◎ | ● |
| 5 | The turnover of the new product innovation in the market | TRNMKT | ● | ● | ● |
| 6 | The turnover of the only new product innovation in the firm | TRNFRM | ● | ◎ | ● |
| 7 | The turnover of the unchanged or only marginally modified goods | TRNUNG | ◎ | ◎ | ◎ |
| 8 | The development by itself | INHRND | ● | ○ | ○ |
| 9 | The development together with other enterprise* or institutions** | EXTRND | ◎ | ○ | ◎ |
| 10 | The development by other enterprises or institutions | OUTSRC | ○ | ○ | ● |

●: High, ◎: Medium, ○: Low

* *Enterprises include independent enterprises plus other parts of their enterprise group (subsidiaries, sister enterprises, head office, etc.)*

** *Institutions include universities, research institutes, non-profits, etc.*

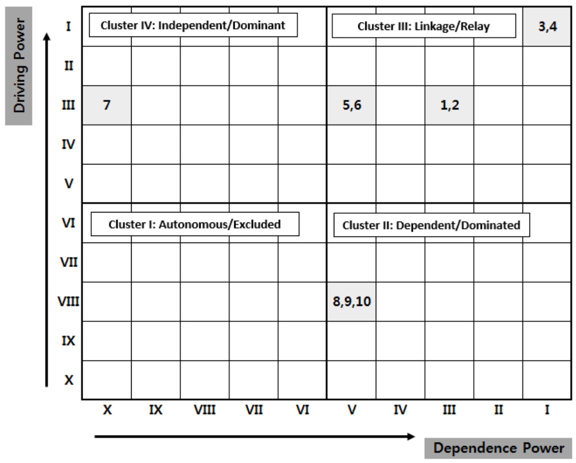

Fig. 2. Driving power and dependence power diagram

The third quadrant with lowest points on both scales indicate the Cluster I named 'autonomous or excluded'. The fourth quadrant with highest point on dependence and lowest point on driver power is the 'dependent or dominated' Cluster II. The first quadrant with its high dependence power and high driver power is the 'linkage or relay' Cluster III. The second quadrant indicates high driver power and low dependence power and is called 'independent or dominant' Cluster IV.

The result of MICMAC analysis is shown in Fig. 2. Cluster I have no product innovation variables. Variables have gathered on one point in Cluster II relatively. We considered product innovation variable 8, 9 and 10 as new product development (NPD). In Cluster III indicating linkage or relay, we recognized that there are three factor group of product innovation variables; product novelty factor including variable 3 and 4, product lunch factor including variable 1 and 2, product sale-contribution factor including variable 5, 6. At driving power '8' and dependence power '1' in Cluster IV, variable 7 is located a faraway place even though it is product sale-contribution factor. We call grouping product innovation variables as product innovation factors

*B. Partitioning and Diagraph*

In the reachability matrix, an iteration process extracts hierarchical levels from relationship of each variable. In other words, the reachability matrix was partitioned by reachability set *R* and antecedent set *A* to obtain ISM hierarchy. Intersections of these two sets were iterated and levels derived for each variable. Reachability set consists of variables with entry '1' in horizontal row corresponding to each variable. In the similar way, antecedent set is generated in vertical columns. For the derivation of levels, if reachability of any variable is a complete subset of antecedent set, this variable was taken out and iteration process can be continued again.

Table 1 shows result of the first iteration. Variable(s) decided the level must be removed from others for next iteration. Until last variable is identified, next iteration process continues. For example, to finish the first iteration in Table 2, the reachability set {1, 2, 3, 4, 5, 6, 8, 9, 10} is a complete subset of its antecedent set {1, 2, 3, 4, 5, 6, 7, 8, 9, 10}. Hence, variable 3 is taken out of the process and is marked on Level I. In this case, variable 4 is marked on the same level. Thereafter, the second iteration can be started except variable 3 and 4. Results of iterations at Level II and V (final level) are described in Table 6 and 7 respectively.

Final reachability matrix which is partitioned can be converted into a lower triangular matrix or conical matrix order by the information of level. It provides a clear indication of each variable's hierarchy. Lower triangular or conical matrix can generate a structural model presenting the results graphically like a network form using vertices and edges. Generally, it is called a directed graph or diagraph. First of all, the diagraph depicts the product innovation variables and their dependencies.

TABLE 5. PARTITIONING OF REACHABILITY MATRIX: FIRST ITERATION

| Variables (i/j) | Reachability Set R | Antecedents Set A | Intersection Set (R∩A) | Level |
|---|---|---|---|---|
| 1. NEWGDS | 1, 3, 4, 5, 6, 8, 9, 10 | 1, 3, 4, 5, 6, 7, 8, 9, 10 | 1, 3, 4, 5, 6, 8, 9, 10 | |
| 2. IMPGDS | 2, 3, 4, 5, 6, 8, 9, 10 | 2, 3, 4, 5, 6, 7, 8, 9, 10 | 2, 3, 4, 5, 6, 8, 9, 10 | |
| 3. NEWMKT | 1, 2, 3, 4, 5, 6, 8, 9, 10 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | 1, 2, 3, 4, 5, 6, 8, 9, 10 | I |
| 4. NEWFRM | 1, 2, 3, 4, 5, 6, 8, 9, 10 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | 1, 2, 3, 4, 5, 6, 8, 9, 10 | I |
| 5. TRNMKT | 1, 2, 3, 4, 5, 8, 9, 10 | 1, 2, 3, 4, 5, 8, 9, 10 | 1, 2, 3, 4, 5, 8, 9, 10 | |
| 6. TRNFRM | 1, 2, 3, 4, 6, 8, 9, 10 | 1, 2, 3, 4, 6, 8, 9, 10 | 1, 2, 3, 4, 6, 8, 9, 10 | |
| 7. TRNUNG | 1, 2, 3, 4, 7, 8, 9, 10 | 7 | 7 | |
| 8. INHRND | 1, 2, 3, 4, 5, 6, 8 | 1, 2, 3, 4, 5, 6, 7, 8 | 1, 2, 3, 4, 5, 6, 8 | |
| 9. EXTRND | 1, 2, 3, 4, 5, 6, 9 | 1, 2, 3, 4, 5, 6, 7, 9 | 1, 2, 3, 4, 5, 6, 9 | |
| 10. OUTSRC | 1, 2, 3, 4, 5, 6, 10 | 1, 2, 3, 4, 5, 6, 7, 10 | 1, 2, 3, 4, 5, 6, 10 | |

TABLE 6. PARTITIONING OF REACHABILITY MATRIX: SECOND ITERATION

| Variables (i/j) | Reachability Set R | Antecedents Set A | Intersection Set (R∩A) | Level |
|---|---|---|---|---|
| 1. NEWGDS | 1, 5, 6, 8, 9, 10 | 1, 5, 6, 7, 8, 9, 10 | 1, 5, 6, 8, 9, 10 | II |
| 2. IMPGDS | 2, 5, 6, 8, 9, 10 | 2, 5, 6, 7, 8, 9, 10 | 2, 5, 6, 8, 9, 10 | II |
| 5. TRNMKT | 1, 2, 5, 8, 9, 10 | 1, 2, 5, 8, 9, 10 | 1, 2, 5, 8, 9, 10 | |
| 6. TRNFRM | 1, 2, 6, 8, 9, 10 | 1, 2, 6, 8, 9, 10 | 1, 2, 6, 8, 9, 10 | |
| 7. TRNUNG | 1, 2, 7, 8, 9, 10 | 7 | 7 | |
| 8. INHRND | 1, 2, 5, 6, 8 | 1, 2, 5, 6, 7, 8 | 1, 2, 5, 6, 8 | |
| 9. EXTRND | 1, 2, 5, 6, 9 | 1, 2, 5, 6, 7, 9 | 1, 2, 5, 6, 9 | |
| 10. OUTSRC | 1, 2, 5, 6, 10 | 1, 2, 5, 6, 7, 10 | 1, 2, 5, 6, 10 | |

TABLE 7. LEVELS OF PRODUCT INNOVATION VARIABLES

| Variables (i/j) | Reachability Set R | Antecedents Set A | Intersection Set (R∩A) | Level |
|---|---|---|---|---|
| 1. NEWGDS | 1, 3, 4, 5, 6, 8, 9, 10 | 1, 3, 4, 5, 6, 7, 8, 9, 10 | 1, 3, 4, 5, 6, 8, 9, 10 | II |
| 2. IMPGDS | 2, 3, 4, 5, 6, 8, 9, 10 | 2, 3, 4, 5, 6, 7, 8, 9, 10 | 2, 3, 4, 5, 6, 8, 9, 10 | II |
| 3. NEWMKT | 1, 2, 3, 4, 5, 6, 8, 9, 10 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | 1, 2, 3, 4, 5, 6, 8, 9, 10 | I |
| 4. NEWFRM | 1, 2, 3, 4, 5, 6, 8, 9, 10 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | 1, 2, 3, 4, 5, 6, 8, 9, 10 | I |
| 5. TRNMKT | 1, 2, 3, 4, 5, 8, 9, 10 | 1, 2, 3, 4, 5, 8, 9, 10 | 1, 2, 3, 4, 5, 8, 9, 10 | III |
| 6. TRNFRM | 1, 2, 3, 4, 6, 8, 9, 10 | 1, 2, 3, 4, 6, 8, 9, 10 | 1, 2, 3, 4, 6, 8, 9, 10 | III |
| 7. TRNUNG | 1, 2, 3, 4, 7, 8, 9, 10 | 7 | 7 | V |
| 8. INHRND | 1, 2, 3, 4, 5, 6, 8 | 1, 2, 3, 4, 5, 6, 7, 8 | 1, 2, 3, 4, 5, 6, 8 | IV |
| 9. EXTRND | 1, 2, 3, 4, 5, 6, 9 | 1, 2, 3, 4, 5, 6, 7, 9 | 1, 2, 3, 4, 5, 6, 9 | IV |
| 10. OUTSRC | 1, 2, 3, 4, 5, 6, 10 | 1, 2, 3, 4, 5, 6, 7, 10 | 1, 2, 3, 4, 5, 6, 10 | III |

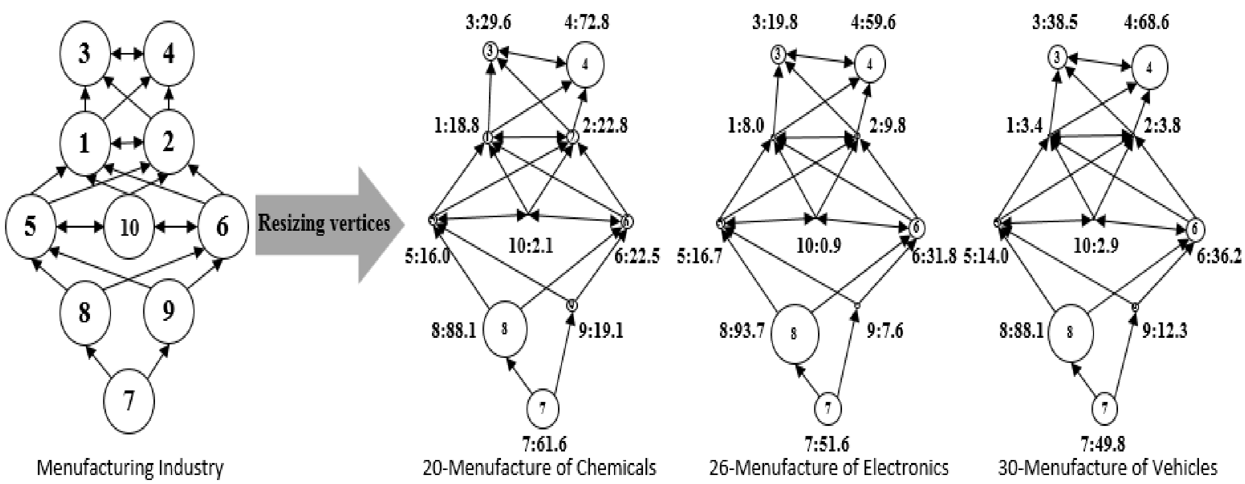


Fig. 3. Result of diagraph analysis with vertex's weight

*C. Quantitative Analysis*

The initial reachability matrix is connected only the direct relationships between any two variables. By drawing the ISM model, a lot of edges can be deleted while the information is still indicated by a set of indirect dependencies. Thereby, the complexity of the visualization is reduced. So this mapping of inter-relationships is a useful method for complex systems with high dependency. Furthermore, the ISM model shows only that there is a connection between two product innovation variables without any information if the impact of this connection is significant or negligible. Hence, we used statistics of three main manufacturing sectors in KIS data so as to figure out their characteristics of product innovation. To find more detailed information about the strength of vertices, we resized every vertex scale using the percentage rate of each variable in Table 8. It means the weight of vertex. This approach ensures the search result for the location of concentrative vertices while keeping the complexity in the diagram.

TABLE 8. % RATE OF PRODUCT INNOVATION VARIABLES FOR MAIN MANUFACTURING SECTORS IN KIS 2012

| Product Innovation Variables | Manufacturing Sectors | | |
|---|---|---|---|
| | 20-Manufacture of chemicals and chemical products | 26-Manufacture of computer, electronic and optical products | 30-Manufacture of motor vehicles, trailers and semi-trailers |
| 1. NEWGDS | 18.8 | 8.0 | 3.4 |
| 2. IMPGDS | 22.8 | 9.8 | 3.8 |
| 3. NEWMKT | 29.6 | 19.8 | 38.5 |
| 4. NEWFRM | 72.8 | 59.6 | 68.6 |
| 5. TRNMKT | 16.0 | 16.7 | 14.0 |
| 6. TRNFRM | 22.5 | 31.8 | 36.2 |
| 7. TRNUNG | 61.6 | 51.6 | 49.8 |
| 8. INHRND | 88.1 | 93.7 | 89.1 |
| 9. EXTRND | 19.1 | 7.6 | 12.3 |
| 10. OUTSRC | 2.1 | 0.9 | 2.9 |

Fig. 3 shows the result of diagraph analysis. Upper left diagraph means general structure on manufacturing industry. We would like to show differences among industry such as chemicals, electronics and vehicles. Size of each circle comes from KIS survey data. Comparison of results in Fig. 3 represented a similar network topology at different manufacturing sectors such as variable 7, 8 and 4. First, we can observe variable 7 (The turnover of the unchanged or only marginally modified goods) and 8 (The development by itself). In the low hierarchical status, Variable 7 leads to variable 8. Variable 8 is bigger than variable 7. On other side, variable 4 (The only new product innovation in the firm) is located in the high hierarchy. Let's gather up threads in the whole situation. It shows a tendency to develop incremental goods using stable earnings in the manufacturing industry.

*D. Qualitative Analysis*

As revealed by the diagraph, it has been observed that the new product innovation in the market (variable 3) and the firm (variable 4) are at the first level of the ISM model in Fig. 4. They lead to the market introduction of new (variable 1) or significantly improved goods (variable 2) at the Level II. The Level III constitutes the development by other enterprises or institutions (variable 10) and the turnover of the new product innovation in the market (variable 5) and the firm (variable 6). The development by itself (variable 8) and together with other enterprise or institutions (variable 9) form Level IV. Lastly, the turnover of the unchanged or only marginally modified goods (variable 7) is supporting all variables in Level V.

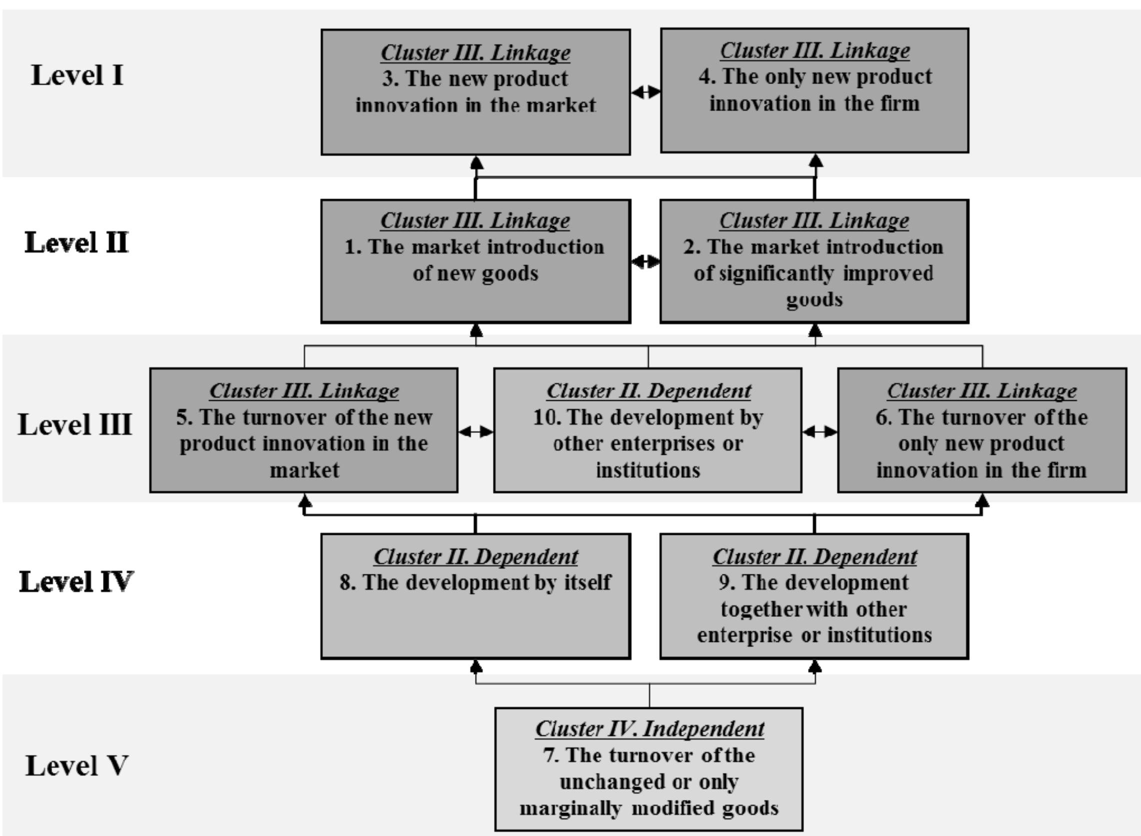


**Fig. 4.** Diagraph ISM-based model of product innovation variables

As soon as observing variable 7 connecting with variable 8 and 9, we recognized that the product development needs basically funds. On the other hands, the information of disconnecting with variable 8 and 9 says that it is difficult to set a rate of in-house R&D and open innovation (OI) in a balanced way. Variable 10 leads to variable 1 and 2. This result provides important guidelines to the decision makers to form supply chain partnership. Decision makers may strategically plan to use outsourcing to meet the right product lunch.

## V. DISCUSSION

### *A. Findings and Implications*

The results of MICMAC and ISM methodologies indicate several meaningful findings. The key findings of our study can be summarized as described below:

- First, we recognized characteristics of product innovation variables. In detail, we can use the relation category as a guideline to select a product innovation variable.
- Second, the driving power-dependence power diagram as shown in Fig. 2 has helped to classify various product innovation variables into four distinct clusters and several factor groups; NPD factor, product novelty factor, product lunch factor and product sale-contribution factor.
- Third, as comparison among manufacturing sectors, it has been suggested several product innovation variables as control variable for incremental or radical product innovation.

In the aspect of implications, innovation policymaker can decide the priority of product innovation variables or factors considering the driving power and dependence power. Also MICMAC analysis shows that there are no identified autonomous product innovation variables. In this case, it indicates that all identified variables have a significant role for product innovation. Hence, it is represented that all variable influence product innovation.

### *B. Limitations and Future Research Direction*

It is necessary to consider the relationships among product innovation variables with direct or indirect influence has made clear its validity. It is desirable for experienced expects and professionals to participate fully in the discussion. This may introduce some variables of bias. And it has not been validated statistically. For future research, it is suggested that Structural Equation Modeling (SEM) method having the testing process for the validity or literature support may be used to corroborate our findings in this study.

## VI. CONCLUSION

Product innovation has been widely recognized as the key driver of sustainable and successful growth for manufacturing firms. This study has attempted to study the inter-relationship among product innovation variables about the main manufacturing sectors in Korea and the underlying MICMAC and ISM methodologies with KIS data. Several meaningful findings and useful implications for innovation policymaker or decision maker has been drawn from our research results and analysis. As shown Fig. 4, we could state that the final classification of product innovation variables leads each manufacturing sector to reaffirm different product innovation strategies. Also MICMAC and ISM methodologies used in this paper are not very complicated way of analysis variables or factors and are easily applied for complex systems.

In the present work, only 10 variables have been used for modeling. More product innovation variables can be identified to product innovation factors. Moreover, the model has not been statistically validated. Future research should have any testing of the validity for model like SEM.

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