Systematic Embodiment of Supply Chain Network through Designing the Optimal Database Structure

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***Abstract*--In the past, many researchers suggested a variety of supply chain network models which encompass both the upstream and downstream sides. However, most of the supply chain models were conceptual network map and focused on individual firm or industry level. In this paper, we analyzed and embodied more substantive supply chain network model based on the optimal database comprised of US patent data, STN International patent data and Harmonized System (HS) code data. We designed 4 relational database sets. First set consists of the list of traded commodities and their HS code. The second is about matching relation between traded products and their raw or intermediate materials. The third is composed of diverse usage databases of raw or intermediate materials compiled by using patent data, and the fourth is about the patent data of individual substances. Then, we implement visualizing the supply chain network from raw materials to traded products by linking 4 database sets. We demonstrate the supply chain network of a medical patch as an application of our technique.**

I. INTRODUCTION

Judging by the current paradigm, the supply chain management is the key strategy of business for entering the era of internetwork competition [25]. A supply chain is a complex system which is made up of flow of material and information, organizations, people, activities during delivering products from supplier to customer. Supply chain activities encompass not only transforming raw materials or natural resources into intermediated or finished products, but conveying products and services to the ultimate customers [25]. The concept of supply chain has been evolved into that of more intricate and expansive network, namely supply chain network or supply network reflecting more complex structure including a higher level of interconnectivity and interaction among more organizations rather than just a linear chain [23, 30, 39, 40]. In the past, it has been increased to discuss the benefits of adopting a network perspective in supply chain management research [8, 12, 27, 28].

Supply chain networks have the characteristic that is stable, even solid, pattern in the relationships among economic and public main agents [30]. However, because of the complexity of supply chain network, an individual agent, such as a supplier of raw material, a distribution dealer of intermediate product and so forth, is unlikely to recognize easily when there is no shared supply chain network map [23, 30]. Namely, objectified and shared model of supply chain network allow agents who has the certain position in the network to readily grasp their position and demanded role and also to identify diverse information which the network can provide, for instance adjacently linked agent and so on [30].

Social network analysis (SNA) has gradually accepted among scholars due to its potentiality and attributes which can embody integrated supply chain networks visually and be helpful to integrate the operations and supply management field [2, 3, 6]. In accordance with Borgatti and Li [3], it is suitable for SNA concept to research a supply chain network in the way that the patterns of inter-firm connection can be analyzed and translated through management of material flow and diffusion of information. However, since researches about since supply chain network by using SNA has focused on each main agent, such as supplier, distributor, and consumer, and their interconnection, these SNA models are somewhat conceptual and just reference models. In addition, that SNA apply to an empirical study of real supply chain networks is not easy, with only a few exceptions (e.g., [6], [9]) because of some defects of SNA; (1) it needs to do a complete enumeration survey and (2) concept of the key SNA metrics (e.g. centrality) is not clarified for theoretically interpreting in terms of supply chain network [7, 23].

Therefore, this study took a different theoretical approach for embodying a supply chain network by using SNA. With regard to existing methods of supply chain network analysis, we have two questions about expressing it as follows; (1) How can we embody supply chain network more systemically and objectively rather than just conceptually?, (2) Is there any other way to express the whole supply chain network about specific products on a broad perspective rather than about certain firms? To resolve these questions, this paper attempted to develop the novel method of embodying a supply chain network on the basis of substantive data of trade customs duties and patents.

The main objective of this study is to embody a supply chain network which abovementioned problems are resolved. To solve the before-mentioned first question, we constructed 4 optimal databases about raw materials, products and their usages that are transacted globally in practice by suing US patent data, STN International patent data and Harmonized System (HS) code data. Also, unlike existing researches about supply networks, firms located in nodes on the existing supply chain network are replaced with raw materials or products, and we linked up among the nodes with relationship of usages to resolve the foregoing second question.

This paper is organized as follows. In Section II, previous

researches on a supply chain network and SNA method. Section III introduces the attributes of our database sets and the research framework. Section IV provides results about applying the model to empirical example, and discussion of results. Section V is about a brief conclusion of our study.

II. LITERATURE REVIEW

A. Supply chain networks and Supply chain management

Christopher [10] defined a supply chain in the following manner; "The supply chain is the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer."

Supply chain network is the developed concept of supply chain that is comprised of inter-connected firms that participate in procurement, use, and processing of raw materials to supply products and services [17, 26]. Supply chain management has two main business processes; (1) material management (inbound logistics), and (2) physical distribution (outbound logistics). Material management covers the complete cycle flow of material ranged from making purchase and controlling internal production materials to not only planning and controlling work-in-process, but warehousing, shipping, and distributing the finished products as well [20]. Physical distribution embraces all outbound logistics activities associated with providing customer service. It contains activities as follows; order receive, inventory deployment, storage and handling, outbound transportation, consolidation, pricing, promotional support, returned product handling, and life-cycle support [5]. Integrating the activities of material management and physical distribution, a supply chain does denote a web of multitudinous stakeholders composed of various suppliers, manufacturers, distributors, third-party logistics providers, retailers, and customers rather than merely a linear chain of one-on-one business relationships [36].

The Global Supply Chain Forum (GSCF) developed the definition of supply chain management as follows: "Supply Chain Management is the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders."

As it is essential for firms to incorporate SCM successfully to hold a lead on the global market, recent competition aspect among firms undergoes a complete transfiguration from competition of the company-versus-company form to that of a supply-chain-versus-supply-chain form [14]. In this emerging competitive environment, the ability to integrate the complicated network of business relationships and anticipate the future alteration of the relevant business' supply chain network will bring the company the eventual success of the single business [4, 11, 15].

In the research field of operations and supply management, there have been varied efforts to describe complex supply chain networks through a systemic viewpoint. Wilding [38] suggested the concept of supply chain complexity to account for dynamic events in supply chain. Surana et al. [37] studied the ways to model supply chain network through diverse complex systems concepts. Mills et al. [29] proposed different methods of strategic approach how supply chain can be managed counting on a firm's location in the supply network, namely if the firm is situated in upstream or downstream, and its seeking position in the supply network, in other words whether the position which a firm pursue is long-term or short-term.

In methodology to analyze model of supply chains, the most well-known model to analyze supply chain is Supply-Chain Operations Reference (SCOR) model developed by the non-profit organization Supply-Chain Council (SCC), the management consulting firm Pittiglio Robin Todd & McGrath (PRTM) and 69 companies [36]. The American Productivity and Quality Center (APQC) Process Classification Framework (PCF) SM is a high-level, industry-neutral enterprise process model that enable organizations to view their business processes in perspective of a cross-industry level [38].

There have been simulation models to research hypothetical supply chain networks [22, 32, 33]. Using case study approach, researchers have studied supply chain networks reflected real world [8, 19, 31]. More recently, employing SNA has got light on studying supply chain networks in some measure. However, there have been a few studies in the operations and supply management field that SNA applied. Borgatti and Li [3] have emphasized the remarkable usefulness of SNA in research of supply chain networks. Choi and Liker [9] employed SNA to examine the implementations of constant development activities in automobile firms. Carter et al. [6] applied SNA to logistics context. Kim et al. [23] applied social network analysis and its relevant key metrics, such as degree centrality, betweenness centrality, complexity, core density and so on, to investigate the structural attributes of supply networks in terms of both materials flow and contractual relationships.

Notwithstanding diverse efforts of researchers, there exists lacking in the studies about a theoretical framework through employing comprehensive application of SNA for explaining supply chain network dynamics [22].

B. Social network analysis (SNA) and Supply chain network

Social network analysis (SNA) is a field of sociology that researches relationships or connections between individuals or specific subjects by using the methods from graph theory, algebra, and statistics [30]. SNA has been employed in a wide range of research field such as sociology, psychology, anthropology, and even epidemiology.

In the operations and supply management field, Choi et al. [7] mentioned that it is easy to approach the study of supply chain networks through using SNA tool. Ellram et al. [16] recognized SNA as a useful methodology to research the influence of supply chains. Carter et al. [6], Borgatti and Li [3], and Ketchen and Hult [21] viewed SNA as a fundamental research tool to advance fields of supply chain management. They have been also aware of, however, the troubles which SNA have such as collecting whole network-level data in supply chain networks, but argued that it is imperative to research the field of operations and supply management to be integrated with other management disciplines.

III. RESEARCH OBJECTIVE AND METHODOLOGY

A. Research objective

The objective of this study is embodying the systematic supply chain network model on the basis of optimal data to be able to well elucidate macroscopic market and to obtain objectivity of the model. To embody substantive and objective supply chain network, our main idea is that it should be visualized based on logically exponible data, that is, visualization of evidence-based supply chain network. Thus, we selected Harmonized System (HS) code data because the products which have the specific HS code number are globally transacted in practice and the HS database includes trading volume and price of the respective products.

Also, most of the existing researches about network analysis with customer-supplier relationships are restricted to specific business or industry, and these networks are visualized based on the transaction data of individual firm [23]. Above all, it is difficult to research visualization of supply chain network based on customer-supplier relationships because of the problem of obtaining the data.

Thus, the visualization of evidence-based supply chain can have significance in the field of supply chain management in itself.

B. The optimal databases

To accord with the aforementioned purpose, we design the 4 optimal databases through employing US patent data, STN International patent data and HS code data.

HS code, tariff nomenclature, is an internationally standardized system of names and numbers to classify traded products [18]. HS code's a series of 6 digits which mean general product categories are assigned by World Customers Organization (WCO), and countries adopting the system then set additional 4 digits to cover commodities in more detailed levels [34]. So, 10 digits are commonly allocated in each of commodities which are transacted globally. We draw up a list of HS codes and their corresponding commodity names in the first database, as depicted in Table 1. Total number of HS codes in the first database is 33143. Commodities which own individual HS code are traded in real world, and there are quantitative data such as total traded amount and price of importing or exporting each commodity.

TABLE 1. AN EXAMPLE OF THE LIST OF HS CODES AND THEIR CORRESPONDING COMMODITY NAMES

HS code	Commodity Name	sub-Product
0101.21-1000	Pure-bred breeding horse	Horse (for farm breeding)
0101.21-9000	Pure-bred breeding horse	Horse (except 0101.21-1000)
0101.29-1000	Horse	Horse (for racing)
…	…	…
3921.19-9030	Other plate of amino-resin polymer	Other plate of amino-resin polymer (cellular)
3921.19-9030	Other sheet of amino-resin polymer	Other sheet of amino-resin polymer (cellular)
3921.19-9030	Other film of amino-resin polymer	Other film of amino-resin polymer (cellular)

TABLE 2. AN EXAMPLE OF THE LIST OF MATCHING BETWEEN HS CODE AND CASRN

HS Code	CASR No	Material Name	Commodity Name	sub-Product
0601.10-4000	p060110_4		Dormant bulb, tuber, tuberous root, corm, crown and rhizome	Of hyacinthus
0601.10-4000	84-66-2	Diethyl phthalate		
0601.10-4000	85-68-7	Butyl benzyl phthalate		
0601.10-4000	84-61-7	Dicyclohexyl phthalate		
0601.10-5000	p060110_5		Dormant bulb, tuber, tuberous root, corm, crown and rhizome	Of gladiolus

Each commodity with HS code can be regarded as raw materials, intermediate products, or finished products. However, since most of them are close to finished products, it is insufficient to embody supply chain network from raw materials to finished products by HS code list. Therefore, we introduce another data which are able to represent raw materials or intermediate products, called a Chemical Abstracts Service Registry Number (CASRN or CAS number).

TABLE 3. AN EXAMPLE OF CLASSIFIED USAGE TABLE OF CASRN

CAS No	Commodity Name	sub-Product	Usages of Chemical	Usages of Electric	Usages of Mechanic	Usages of Medical & Bio	Usages of Others
2597-03-7	PAP	PAP	Acaricide; Detergent; Fungicide; Insecticide; Pesticide				
25971-63-5	Polycarbonate (general)	Polycarbon-ate (sheet)	Beverage transparent multilayer plastic bottle; Camera lens; Fiber optic; Film; Injection molding; Light reflection part; Optical disk substrate; Optical molding; Photo fiber; Plastic window	Battery pack; Multilayer battery cathode current collector; Connector; Diffuser plate; Electronics housing; Flat panel display fixing frame; Light guide plate; Liquid crystal	Cluster; Door handle; Extension; Gearing tool; Roof rail; Wheel cap	Beverage tank; Mechanical heart; Three-way stopcock	Carport; nameplate of highway fence; Safety helmet; Sunglasses
25987-08-0	Polyethylene-imine	Polyethylene-imine	Anchoring agent; Basic brightener; Chelate resin; Crystal-grained agent; Dyeing auxiliary agent; Ion exchange resin; Metal plating additive				
2601-13-0	Isoamyl caproate (2-methylbutyl caproate)	Isoamyl caproate(2-methylbutyl caproate)	Flavor				Daily Flavor; Food Flavor; Industrial Flavor

CASRN is a unique numerical identifier assigned by Chemical Abstracts Service (CAS) to every chemical substance described in the open scientific literature (currently including those described from at least 1957 through the present), including organic and inorganic compounds, minerals, isotopes, alloys and nonstructurable materials (UVCBs, of unknown, variable composition, or biological origin) [1]. Generally, chemical substances are used in raw materials or intermediate materials during processes of producing a certain commodity. We matched commodities with HS code to identical chemical substances with CASRN in the second database. If commodity in the first database has matched one in CASRN, we can regard it as a raw material or an intermediate product. If it is vice versa, it can be considered finished product and we assigned it to finished product code we stipulate made up of alphabet 'p' and 7 digits of HS code. An example of the second database is shown in Table 2.

Each chemical substance with CASRN may have specific usages during certain processes to produce something. Thus, we additionally set the third and fourth database about usages of CASRN through using US patent and STN International patent data. The fourth database is about information of patents that is linked to a certain CASRN. Based on information of the fourth data, we established the third database that represents usages of each CASRN. Each usage of CASRN is further subdivided by field of industry such as chemical, mechanic, electric, bio & medical and others. Detailed examples of the third and fourth database are represented Table 3 and 4, respectively.

C. Research framework

With these 4 optimal databases, we conceptualize the supply chain network as the system encompassed from raw materials to finished products, as depicted Fig. 1. Unlike existing studies, we defined nodes on a supply chain network as raw materials, intermediate or finished commodities represented by commodity names with HS code or chemical substances with CASRN. We also view the meaning of link between nodes as usages or results of processing. As Fig. 1, 1st band means the connection between HS-codified or CASRN-codified raw materials and their intermediates, and 2nd band is the system that is about transferring raw materials (or intermediates) to primary components or finished products. Finally, 3rd~Nth bands mean the supply chain network based on HS-codified components, not raw materials. By the 4 optimal databases, it can be expressed for the supply chain network of a certain raw material to spread out to diverse fields of industry. The anticipated supply chain network diagram of the supply chain network based on these optimal databases is illustrated in Fig. 2.

TABLE 4. AN EXAMPLE OF THE PATENT DATA OF EACH CASRN

Concept or Classification	Title	Controlled or Index Terms	USES (Uses)
5-4 (Agrochemical Bioregulators)	Combinations of biological control agents and insecticides	1314-84-7D,Zincphosphide,mixts.containing RL: AGR (Agricultural use); BIOL (Biological study); USES(Uses) (combinations of biol. control agents and insecticides)	combinations of biol. control agents and insecticides
5-5 (Agrochemical Bioregulators)	Toxicology and histopathology of some rodenticides and palatable food items combinations on the common mice Mus musculus var. albus in Egypt	1314-84-7,Zincphosphide RL: BSU (Biological study, unclassified); BUU (Biological use, unclassified); BIOL (Biological study); USES (Uses) (toxicol. and histopathol. of rodenticides and palatable food items combinations on common mice)	toxicol. and histopathol. of rodenticides and palatable food items combinations on common mice
76-5 (Electric Phenomena) Section cross-reference(s): 73	Manufacture of avalanche semiconductor light-accepting device having zinc-diffused guard ring	1314-84-7, Zincphosphide(Zn3P2) RL: USES(Uses) (zinc diffusion source, for preparation of guard ring, for avalanche semiconductor light-accepting device)	zinc diffusion source, for preparation of guard ring, for avalanche semiconductor light-accepting device
52-2 (Electrochemical, Radiational, and Thermal Energy Technology)	Thin-film cadmium telluride and zinc phosphide solar cells	1314-84-7 RL: USES(Uses) (for photoelec. solar cells, deposition and characterization of thin-film)	for photoelec. solar cells, deposition and characterization of thin-film

IV. EMPIRICAL ANALYSIS

A. Data and Software

In order to apply this model to actual industry, we need to select a certain product to express the supply chain network with it as a center. It is difficult for too broad industry or market to express the supply chain network meaningfully. Thus, to get susceptibility to significant interpretations, we selected the finished commodity produced by small and medium-size enterprise (SME) specialized in making a specific product.

As a part of the project performed by Korea Institute of Science and Technology Information (KISTI), we investigated demands of SMEs which want to analyze the supply chain network of their main products. Among lots of SMEs' requests, in this paper, we introduce the supply chain network of "a medical patch" as an application of our technique. To visualize the supply chain network, we use the software of NetMiner 3.0., developed by Cyram as a SNA tool.

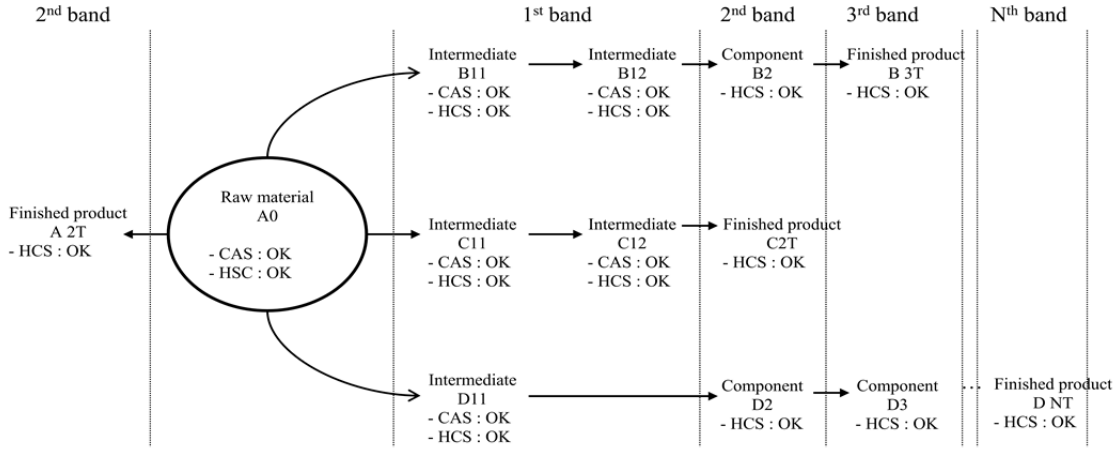

Fig. 1. The embodying mechanism of the optimal databases-based supply chain network

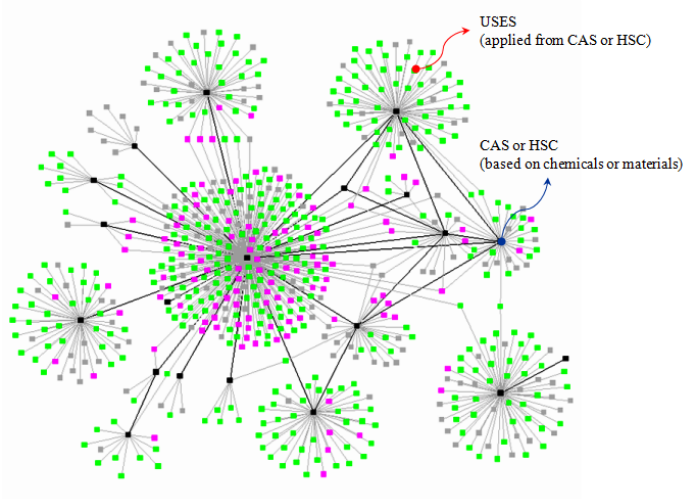

Fig. 2. The anticipated supply chain diagram of the supply chain network based on the optimal databases

TABLE 5. HS CODE NUMBERS AND THEIR COMMODITY NAMES RELATED TO A MEDICAL PATCH

HS code	Commodity Name	sub-Product
3006.10-1010	Sterile surgical catgut	medical patch
3006.10-1020	Sterile suture material	Sterile absorbable surgical yarn (medical patch)
3006.10-1020	Sterile suture material	Sterile absorbable dental yarn (medical patch)
3006.10-1020	Sterile suture material	Sterile suture material (medical patch)
3006.10-2000	Sterile tissue adhesive	Sterile tissue adhesive (for surgical wound closure)

TABLE 6. HS CODES AND THEIR MATCHING CASR NUMBER RELATED TO A MEDICAL PATCH

HS Code	CASR No.	Product name
1212.29-3090	25038-32-8	Styrene block copolymer(S-I-S) (Characteristics of the synthetic rubber)
2910.90-0000	30499-70-8	Trimethylolpropane polyglycidyl ether
0510.00-9020	688-84-6	2-Ethylhexyl methacrylate
2910.90-0000	30499-70-8	Trimethylolpropane polyglycidyl ether
3903.90-9000	25038-32-8	Styrene block copolymer(S-I-S)
2918.11-2000	18917-91-4	Aluminium lactate
2849.90-1000	12070-10-9	Vanadium carbide
2917.37-0000	120-61-6	Dimethyl terephthalate
2918.23-1010	119-36-8	Methyl salicylate
2909.30-3000	101-84-8	Diphenyl ether
2902.50-0000	100-42-5	Styrene monomer
3906.90-9000	9003-04-7	Sodium polyacrylate
0709.51-7000	2873-97-4	Diacetone acrylamide
3901.30-0000	24937-78-8	Ethylene vinyl acetate copolymer

First, we extracted the data about a medical patch from the 1st and 2nd database. The extracted data means HS code number of a medical patch and its matching CASRN data (Table 5, 6). Then, we abstracted the usage data aforementioned matching CASRN and made the edge list which needed to visualize social network map. Finally, with the edge list about usages of a medical patch, we embodied the supply chain network of a medical patch, depicted as Fig. 3.

B. The result of visualizing the supply chain network of medical patch

According to Table 6, we can identify the raw materials (or intermediates) used in process producing a medical patch. Most of CASRN is related to polymerized compound and some of them are about chemical compounds that assign adhesive capability to a medical patch. When we embodied the supply chain network about a medical patch by using each of relationship between HS code and CASRN, the result is similar to expected conceptual map, depicted as Fig. 2.

Specific usages of the CASRN related with a medical patch show a variety of aspects in diverse fields. Detailed usages are shown in Table 7. We can infer that some firms producing a medical patch can not only identify varied raw materials of it, but how they can diversify business with their core technology above a certain industry with this embodied supply chain network.

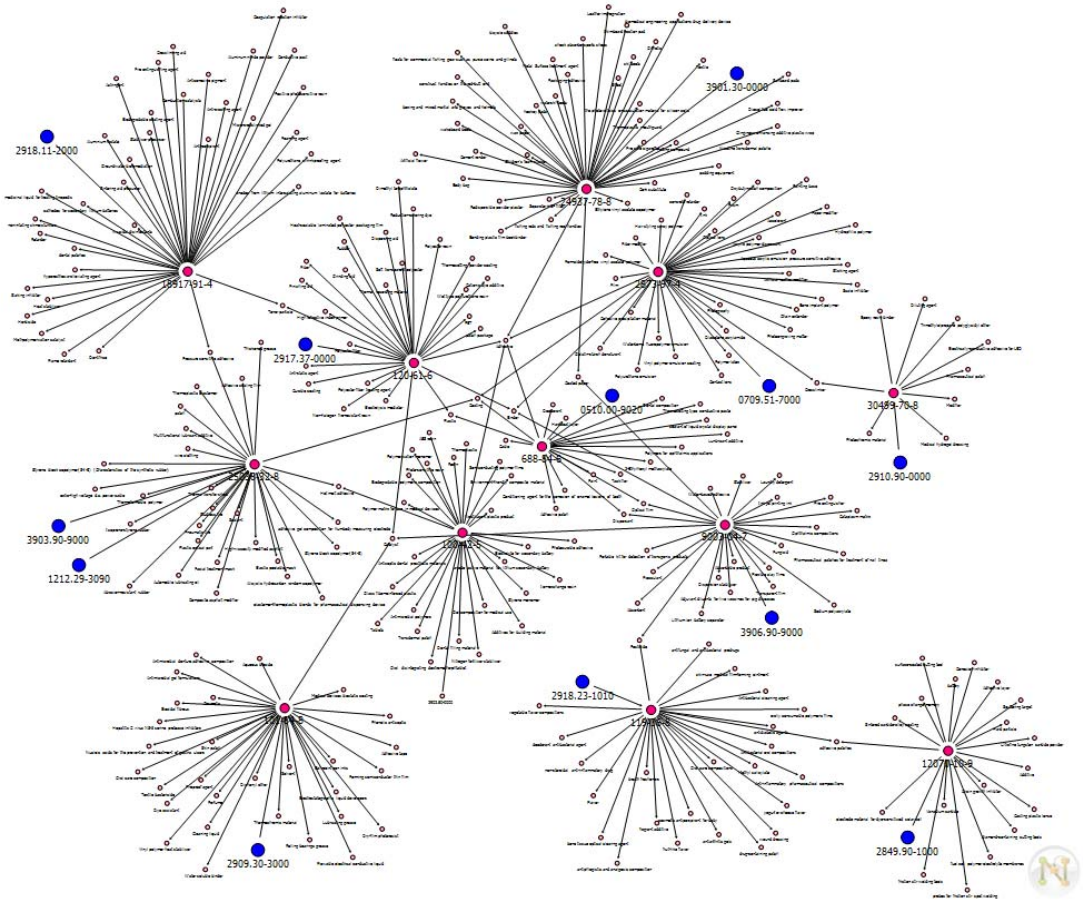

Fig. 3. The supply chain network of a medical patch

TABLE 7. SPECIFIC USAGES OF THE CASRN RELATED WITH A MEDICAL PATCH

CAS No	Commodity Name	sub-Product	UsageChem	UsageElec	Usage Mech	Med&Bio	Others
24937-78-8	Ethylene vinyl acetate copolymer (high concentation of vinyl acetate)	Ethylene vinyl acetate copolymer	Adhesive; Artificial flower; Redispersible powder plaster; Cement render; Bonding plastic film bookbinder; Children's foam sticker; Clinginess-enhancing additive plastic wrap; Coated paper; Diesel fuel cold flow improver; Separator HEP filter; Fire safe cigarette; Leather impregnation; Body bag; Nicotine transdermal patch; Metal Surface treatment agent; Orthotic	the photovoltaic encapsulation material for silicon cells; wax paper		biomedical engineering applications drug delivery device	padding equipment; ski boots; bicycle saddles; hockey pads; boxing and mixed martial arts gloves and helmets; wakeboard boots; waterski boots; fishing rods and fishing reel handles; shock absorber sports shoes; floats for commercial fishing gear such as purse seine and gillnets
2873-97-4	Diacetone acrylamide	Diacetone acrylamide	Accelerant; Acrylic polymer dispersant; Adhesive; Aqueous acrylic emulsion pressure sensitive adhesive; Artificial leather modifier; Binder; Bone implant polymer; Chain extender; Coating; Cohesive precipitation material; Optical lens; Contact lens; Crosslinker; Fiber modifier; Film; Formaldehyde-free vinyl acetate polymer; Hair styling spray polymer; Hydrophilic polymer			Gelatin-starch denaturant	concrete retarder
9003-04-07	Sodium polyacrylate	Sodium polyacrylate	Absorbent; Binder; Catalyst; Coated paper; Dispersant;	Lithium ion battery		Ophthalmic compositions;	Absorbable product; Transparent film;

			Dispersion stabilizer; Fire extinguisher; Flocculant; Fungicide; Ink-jet printing ink; Laundry detergent; Pesticide; Stabilizer; Water-based adhesive	separator		Cataplasm matrix; Adjuvant diluents for live vaccines for pig diseases	Portable kit for detection of transgenic products; Flexible clay films; Optical film
100-42-5	Styrene monomer	Styrene monomer	ABS resin; Adhesive; Biodegradable polymeric composition; Hot melt adhesive; Ion-exchange resin; Nitrogen fertilizer stabilizer; Photocurable adhesive; Polymerization monomer; Resin; Thermoplastic	Electrolyte for secondary battery; anode active material for lithium secondary battery		Tablets; Gel composition for medical use	Glassfiber-reinforced plastic ;Environment-friendly composite material;
101-84-8	Diphenyl ether	Diphenyl ether	Aqueous biocide; Biocidal fibrous; Catalyst; Cleaning liquid; Cosmetic; Dye assistant; Fireproof agent; Medical devices biostatic coating; Perfume; Phenolic antiseptic; Solvent; Textile bactericide; Vinyl polymer heat stabilizer; Water soluble binder	Forming semiconductor thin film		Hepatitis C virus NS-3 serine protease inhibitors; Oral care composition; Skin patch; Nucleic acids for the prevention and treatment of gastric ulcers	Lubricating grease; Rolling bearings grease; Ball-point pen inks; Flowable electrical conductive liquid; Electrostatographic liquid developers; Thermochromic material; Adhesive tape
119-36-8	Methyl salicylate	Methyl salicylate	Antibacterial cleaning agent; Flavor; Pesticide			antidiabetic agents; non-steroidal anti-inflammatory drug; antifungal and antibacterial prodrugs; skin-use medical film-forming ointment	yogurt or cheese flavor; fruit-like flavor; vegetable flavor compositions; breath fresheners; cosmetic antiperspirant for baby; Oral care composition; fragrant additive
120-61-6	Dimethyl terephthalate	Dimethyl terephthalate	Adhesive; Anti-static agent; Binder; Catalyst; Cationic dye additive; Curable coating; Dispersing aid; Electrolysis mediator; Fiber; Finishing aid			patch package	
12070-10-9	Vanadium carbide	Vanadium carbide	Additive; Adhesive layer; Casting plastic lense; Corrosion inhibitor; Grain growth inhibitor; Hard particle; Sintered carbide-alloy coating; Sputtering target; Ultrafine tungsten carbide powder	battery; electrode material for dye-sensitized solar cell; phase change memory	diamond-containing cutting tools; probes for friction stir spot welding; surface-coated cutting tool	adhesive patches	
18917-91-4	Aluminium lactate	Aluminium lactate	Aluminum nitride powder; Anti-cracking agent; Anti-perspirant; Anticorrosive pigment; Astringent; Groundwater bioremediation; Coagulation reaction inhibitor; Combustion catalysts; Conductive past; Crosslinking aid; Dentifrice; Fire extinguishing agent; Foaming agent; Flame retardant; Foaming agent	cathodes for secondary lithium batteries; anodes from lithium intercalating aluminum lactate for batteries		Biodegradable coating agent; medicinal liquid for treating tinepedis; dental patches; hyperesthesia-alleviating agent; virucidal disinfectants	nonirritating skin moisturizers
25038-32-8	Styrene block copolymer(S-Isoprene-S)	Styrene block copolymer(S-I-S)	Abrasion-resistant rubber; Adhesive sealing film; Alicyclic hydrocarbon random copolymer; Automobile lubricating oil; Coating; Composite asphalt modifier; Elastic peelable mask;	Wire clothing		patch; elastomer-thermoplastic blend	
30499-70-8	Trimethylolpropane polyglycidyl ether	Trimethylolpropane polyglycidyl ether	Crosslinker; Diluting agent; Epoxy resin binder; Modifier; Photochromic material	Electrically-conductive adhesive for LED		Pharmaceutical patch; Medical hydrogel dressing	
688-84-6	2-Ethylhexyl methacrylate	2-Ethylhexyl methacrylate	Adhesive; Cable; Coating; Deodorant; Dispersant; Hardcoat	sealant of liquid crystal display		Adhesive patch; Dental	

			layer; Lunbricant additive; Optical film; Paint; Plastic; Tackifier; Thermosetting type conductive paste	panel		composition; Conditioning agent for the corrosion of enamel lesions of teeth	
30499-70-8	Trimethylolpropane polyglycidyl ether	Trimethylolpropane polyglycidyl ether	Crosslinker; Diluting agent; Epoxy resin binder; Modifier; Photochromic material	Electrically-conductive adhesive for LED		Pharmaceutical patch; Medical hydrogel dressing	
25038-32-8	Styrene block copolymer(S-Isoprene-S)	Styrene block copolymer(S-I-S)	Abrasion-resistant rubber; Adhesive sealing film; Alicyclic hydrocarbon random copolymer; Automobile lubricating oil; Coating; Composite asphalt modifier; Elastic peelable mask; High-viscosity modified asphalt; Hot melt adhesive; Isoprene-styrene rubber; Facial treatment mask; Multifunctional lubricant additive	extra-highvoltage d.c. power cable; wireclothing		patch; elastomer-thermoplastic blends for pharmaceutical dispensing device; adhesive gel composition for human body measuring electrode	

V. CONCLUSION

In this study, we introduced the novel method of embodying the systemic supply chain network by using the 4 optimal databases. In order to express supply chain network objectively, we used HS code, CASRN data and patent data. Each original data is not arranged, so we transform each of them into suitable form to embody the supply chain network optimally.

Consequently, we can visualize the supply chain network in terms of not individual firm level, but macroscopic process of production level. Therefore, the embodied supply chain network based these optimal databases are expected to have characteristics as follows; (1) due to HS code of trade tariff data, it includes actual trade data, (2) individual elements (nodes) are inter-connected with coordinated linkage of usages based on effective patent data, and (3) the embodied supply chain network can be interpreted as a whole market or cross-industry perspective.

In the visualized supply chain network, individual firms can confirm the flow of materials and commodities in whole market including intra-industry and cross-industry. Thus, they also detect usages or markets which they couldn't recognize or can penetrate, that is, they can obtain and analyze technological opportunities.

In addition, if firms detect their novel technology opportunities through the systemic supply chain network, it is easier for them to secure resilient supply network, which can adapt to risk that influences their capacities and operate flexibly regardless of market fluctuation.

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However, because our optimal databases have peculiarity in their structure, it has limits to embody and visualize the supply chain networks by existing SNA programs, such as NetMiner, Gephi and so on. Also, there still exist some matters of interpreting or analyzing such supply chain network. So, we are developing the optimal system which can embody and analyze this HS and CASRN data-based supply chain network.

Since HS code data includes the quantitative data such as the amount or price of traded products, we have a plan to connect between supply chain network and this quantitative data to interpret the meaning of supply chain and trends of trade simultaneously in the near future. Our study is believed to help understand the supply chain network more systemically.

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