Reference Investigation Concerning Utilization of 3D Information in Construction Industry

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Abstract: Recently, CALS/EC is rapidly being promoted with the development of information technology. CALS/EC aims at an increase in efficiency of business by carrying out information exchange, cooperation, sharing, and reuse for digital results in the process of the life cycle of investigation, planning, design, construction, and maintenance management in public works. In CALS/EC, attention is being focused on utilization of 3D information for CAD or GIS. In order to promote CALS/EC in the future, it is very important to utilize 3D information. The purpose of this present research is to undertake reference investigation about practical utilization of 3D information in the construction industry. Moreover, the present condition of practical utilization of 3D information in the construction industry was analyzed.

Keywords : 3D Information, Construction Industry, CALS/EC, Reference Investigation

1. Introduction

In recent years in the construction industry, Construction CALS/EC is being aggressively promoted[1)-3)]. Construction CALS/EC is an organization with a goal to improve business efficiency by computerizing documents of investigation, planning, design, construction, and maintenance management – which complement to life-cycle process – of public works and projects, and by promoting information exchange, collaboration, sharing, and reuse[4)-6)]. Recently, among electronic information that is being used in the construction industry, application of 3D information is gaining attention[7)-8)]. In the construction industry, there are many occasions when 3D information is handled by using systems such as CAD and GIS[9)]. For the promotion of the next generation of the CALS/EC, effective utilization of 3D information is extremely important.

In order to use 3D information in the construction industry, it is necessary to grasp the current situation. By recognizing at which construction field and business phase the 3D information is currently being used, strategy for effectively using 3D information can be planned.

Therefore, in this research, investigation on documents related to the use of 3D information of the construction industry was performed. In documents such as academic thesis papers and technology reports, the latest and advanced cases are reported, and investigating on those cases is extremely useful. The documents are collected, and by collectively analyzing each of the documents, effective use of 3D information in the construction industry will be studied.

2. Purpose of Research

In this research, documents related to application of 3D information of the construction industry are investigated. From each of the documents, keyword is extracted. Also, by using the extracted keyword, the documents are classified into category of construction field and business phase.

To the classified documents, “analysis of the number of documents in terms of construction field / business phase” and “analysis of keyword frequency in terms of construction field / business phase” will be performed. From the analysis, on what kind of

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construction field and business phase that the 3D information is being used will be grasped. In addition, by performing frequency analysis on the extracted keywords, we will be able to determine what kind of technology is gaining attention in each construction field and each business phase.

By the above investigation, situation of application of 3D information in the construction industry will be studied.

3. Document Gathering and Keyword Extraction

In this research, as a prior step of document investigation, 2 processes of "gathering and sorting of documents" and "optimization of keyword extraction" were performed. Each result is summarized below.

(1) Gathering and Sorting of Documents

As a first task of document investigation, documents related to the application of 3D information were collected. Database used in document collection

Table 1 Combinations of Keywords that were Used in Document Search and their Document Count

Combinations of Keywords				Number of Documents
1	3D	CAD	Structure	34
2	3D	CAD	Construction	50
3	3D	CAD	Survey	56
4	3D	CAD	Execution	54
5	3D	CAD	Maintenance management	10
6	3D	GIS	Structure	20
7	3D	GIS	Construction	11
8	3D	GIS	Survey	23
9	3D	GIS	Execution	3
10	3D	GIS	Earthquake-proof	2
11	3D	Prevention of disasters		19
Total				282

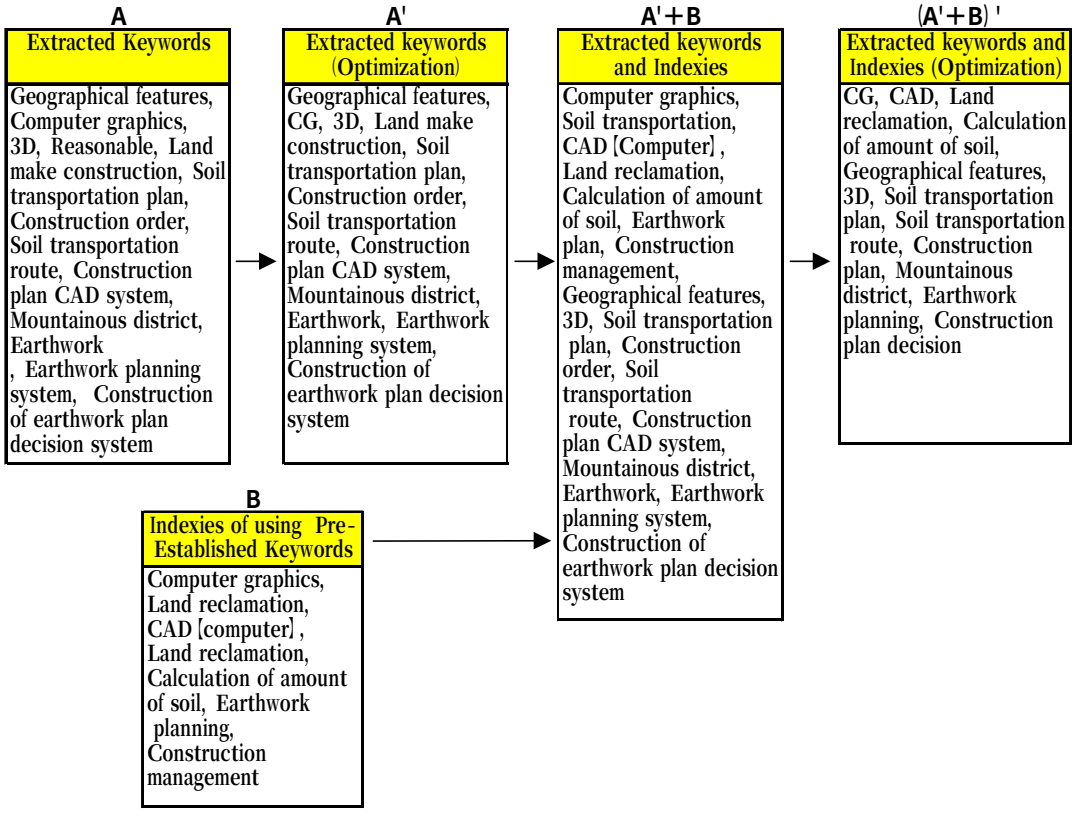

Fig.1 Example of Extracted and Optimized Keywords

is JOIS (JST Online Information System) that is offered by Japan Science and Technology Agency (JST). The gathering of the documents was done by document search by keywords. In the search, combination of 11 keywords was used. In this research, in order to perform investigation on application of 3D information, keyword "3D" was adopted to all of the combinations. In addition, keywords of "CAD" and "GIS", which have deep relations with computerization of construction industry, were used. Search result for each of the 11 combinations that used other keywords is as shown in **Table 1**. Document search with AND search was performed by using the keyword. As a result of the search, 282 documents were gathered and sorted.

(2) Extraction and Optimization of Keywords

In order to classify the collected documents into construction field or business phase, extraction of optimum keywords for every documents was performed. This task will be performed in the following 5 processes:. a) extraction of keywords from document abstract, b) optimization of the extracted keywords, c) production of index using pre-established keywords, d) combination of extracted keywords and the indexes, e) optimization of keywords and indexes. Details of each process will be explained below. Example of keyword extraction and optimization is as shown in **Fig.1**.

a) Extraction of Keywords from Document Abstract

In keyword extraction, after breaking down each of the document's abstract in terms of words using morphological analysis, they were extracted manually. Important keywords in each of the document were extracted.

b) Optimization of Extracted Keywords

Optimization of the extracted keyword was performed. Because the number of the extracted keywords will be enormous, executing process optimization will be required. For process optimization, keyword regularization, keyword decomposition, and deletion of unnecessary keyword are performed.

By keyword regularization, keywords that have many expressions with the same meaning were unified. Rules of regularization were set manually, and by using calculation program and by following the rules, keyword regularization was performed. For example, 3 words of "car-navi", "car navigation", and "car-navi system" were unified into an expression "car navigation system".

In keyword decomposition, keywords that have multiple meanings were decomposed. Decomposition rules were created manually, and by using calculation software and by following the rules, the keyword decomposition was performed. For example, keyword "3D CAD" was broken down into 2 words -"3D" and "CAD".

Words that were unsuitable as a keyword were deleted from the keyword list.

c) Production of Index by Using Pre-Established Keywords

Index was produced using keywords that were pre-established in a document.

d) Combination of Extracted Keywords and Indexes

The list of optimized keywords from b) and the index produced from c) was grouped together in order to make a new keyword list.

e) Optimization of Keywords and Indexes

To the keywords that were grouped in d), same optimization process from b) was performed again.

4. Analysis on Documents in Terms of Construction Field / Business Phase

In this analysis, classification of documents based on the extracted keywords is performed. The classification was done in terms of construction field and business phase. Documents of construction field were classified under 20 categories such as roads and underground structures, and documents of business phase were classified under 10 categories such as investigation and planning, summary and detailed design – total of 200 categories were used to classify the documents. Next, for each of the documents, sorting number of classified category was assigned. Number of documents and document sorting number of construction field / business phase are as shown in **Table 2**.

There is a case when the number of document is none or extremely small under a category. Therefore, by only extracting category with more than 5 documents, investigation is done on 10% of the total 200 categories. Headings that have more than 5 documents were placed on a spreadsheet.

After classifying the documents, analyses on relatedness of construction field / business phase and on documents related to 3D information were performed.

"Analysis on number of documents in terms of construction field", "analysis on number of documents in terms of business phase", and "analysis on number of documents in terms of construction field / business level" were performed. Each analysis is explained below.

Table 2 Document Count and Document Sorting Number for Each Category

Construction Field \ Business Phase			Investigation and Planning		Summary and Detailed Design		Addition		Construction		Maintenance Management: Investigation and Planning		Maintenance Management: Summary and Detailed Design		Maintenance Management: Addition		Maintenance Management: Construction		Others: Disaster Prevention		Others: Lifecycle	
			1		2		3		4		5		6		7		8		9		10	
Roads	A	Roads Sidewalk Level Crossing Point Overpass Point Road Rest Facilities General Structures	A1	13	A2	10	A3	1	A4	5	A5	4	A6	0	A7	0	A8	1	A9	1	A10	0
Underground Structures	B	Underground Crosswalk Cooperation Structures Electric wire Cooperation Structures	B1	2	B2	0	B3	1	B4	0	B5	1	B6	0	B7	0	B8	0	B9	0	B10	0
Basement Parkings	C	Basement Parkings	C1	0	C2	0	C3	0	C4	0	C5	0	C6	0	C7	0	C8	0	C9	0	C10	0
Tunnel Structures	D	Mountains Tunnels Shield Tunnels Excavation Tunnels	D1	0	D2	1	D3	0	D4	0	D5	0	D6	0	D7	0	D8	0	D9	0	D10	0
Bridges	E	Bridges	E1	0	E2	8	E3	4	E4	4	E5	3	E6	0	E7	0	E8	2	E9	0	E10	0
River Structures	F	Shore Protections Gutter gate, Gutter tube, Weir, Sluice, and Drain Machine Places Bed Consolidation Works	F1	1	F2	0	F3	0	F4	0	F5	0	F6	0	F7	0	F8	0	F9	1	F10	0
Coast Structures	G	Embankment, Shore Protection, and Parapet Pier Offshore Breakwater, Artificial Reef, and Kehatstsmi Climax and Tidal Wave Breakwater Artificial Cape Artificial Coast Incidental Equipments	G1	1	G2	1	G3	0	G4	1	G5	3	G6	0	G7	0	G8	0	G9	0	G10	0
Preventing Sand Erosion Structures	H	Barrier to Prevent Landslides and Floor Hardening Workers Passage Workers Mud Fow Measures and Driftwood Measures Shore Protection Workers Hillside Workers	H1	0	H2	0	H3	0	H4	0	H5	0	H6	0	H7	0	H8	0	H9	1	H10	0
Dam Structures	I	Gravity Concrete Dams Zone Type Fildams	I1	0	I2	2	I3	1	I4	4	I5	1	I6	0	I7	0	I8	0	I9	0	I10	1
Urban	J	Housing Lot Developments Park(Infrastructure) Drainage(Conduit)	J1	17	J2	1	J3	0	J4	2	J5	4	J6	0	J7	0	J8	0	J9	8	J10	0
Structures	K		K1	3	K2	10	K3	2	K4	15	K5	3	K6	1	K7	0	K8	0	K9	0	K10	0
Drainages	L		L1	0	L2	0	L3	0	L4	1	L5	0	L6	0	L7	0	L8	0	L9	1	L10	0
Topography, Foundation, and Mountain Related	M		M1	8	M2	1	M3	0	M4	3	M5	0	M6	0	M7	0	M8	0	M9	6	M10	2
Railways	N		N1	1	N2	0	N3	0	N4	1	N5	0	N6	0	N7	0	N8	0	N9	1	N10	0
Golf Courses	O		O1	1	O2	0	O3	0	O4	0	O5	0	O6	0	O7	0	O8	0	O9	0	O10	0
Plant and Power Plant Related	P		P1	7	P2	5	P3	1	P4	5	P5	3	P6	0	P7	0	P8	1	P9	3	P10	0
Ruins	Q		Q1	1	Q2	0	Q3	0	Q4	0	Q5	3	Q6	0	Q7	0	Q8	1	Q9	0	Q10	1
Steel Towers	R		R1	0	R2	0	R3	0	R4	1	R5	0	R6	0	R7	0	R8	0	R9	0	R10	0
Composite Structures	S		S1	5	S2	4	S3	0	S4	5	S5	2	S6	0	S7	0	S8	1	S9	6	S10	2
Others	T		T1	11	T2	4	T3	3	T4	18	T5	2	T6	2	T7	0	T8	1	T9	4	T10	5

(1) Analysis of Number of Documents in Terms of Construction Field

Analysis of number of documents in terms of construction field was performed. The result of the analysis is summarized as shown on the graph (**Fig.2**). That graph is shown that number of documents is focused on "roads" with 35 counts, "structures" with 34 counts, and "urban" with 32 counts. As a reason for this, 3 categories of "roads", "urban" and "structures" have a lot of business cases, and it is expected that they will have a lot of documents related to 3D information. Also, these 3 categories are principle categories in the construction industry. Therefore, the use of 3D information is expanding from the principle construction fields.

Next, as the numbers are large in "bridges", "plant / power plant related", and "composite construction materials", it can be understood that 3D information is also being used in complex construction materials. In other construction fields, the use of 3D information has not been infiltrated as much. It is believed that the overall increase in the use of 3D information in each of the construction fields will be an important factor for promotion of the Construction CALS/EC of the next generation.

(2) Analysis of Number of Documents in Terms of Business Phase

Analysis of number of documents in terms of business phase was performed, and the result was summarized as shown in a radar chart (**Fig.3**).

On the radar chart, it is shown that "construction" and "investigation / planning" categories contain relatively large number of documents, as they have 65 and 58 counts, respectively. From this, it can be understood that 3D information is widely used in the "construction" and "investigation / planning" phases. The use of CAD data is speculated to be the reason for 3D information being widely used in the construction phases of "investigation / planning" and "construction".

In order to promote the Construction CALS/EC, it will be important to smoothly carry out information exchange, collaboration, sharing, and reuse for each business phase. In order to realize this, it is required for every business phase to use 3D information and have smooth flow of the information.

According to this analysis, difference of amount of usage of 3D information between each business phase can be observed. For example, it is shown that use of 3D information is still small in the maintenance management phase, as it only has 39 document counts (compared to the rest). From now on, by uniformly utilizing 3D information for each business phase, information exchange, collaboration, sharing, and reuse of the total life-cycle will be able to function smoothly.

(3) Analysis of Number of Documents in Terms of Construction Field / Business Phase

In this analysis, number of documents that was classified in terms of construction field / business phase is summarized in a form of 3D graph as shown in **Fig.4**. Also, a 3D graph, as shown in **Fig.5**, that only displays categories with more than 5 document counts was produced.

Category of "urban / investigation and planning", with 17 document counts, had the most number of documents that are related to 3D information. The next categories with the most number of documents were "structures / construction" with 15 document counts and "roads / investigation and planning" with 13 document

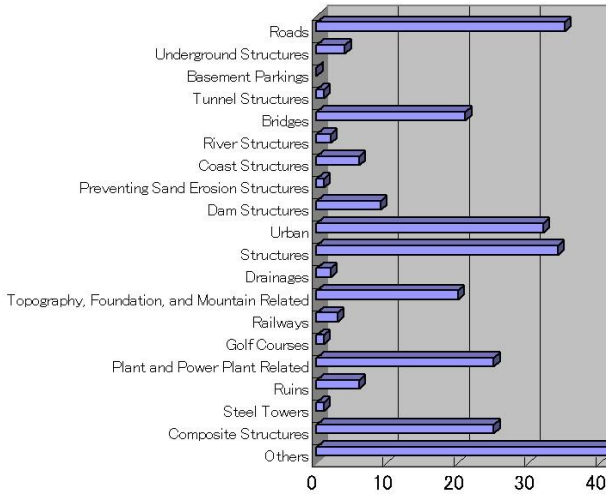

Fig.2 Number of Documents in Terms of Construction Field

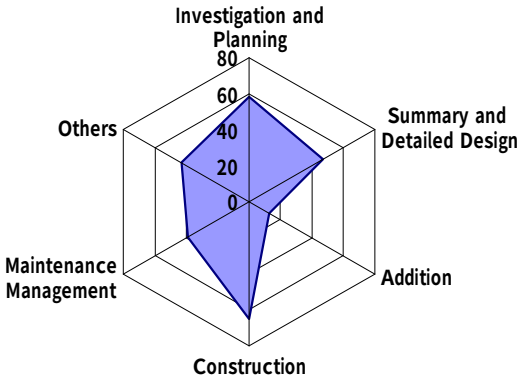

Fig.3 Number of Documents in Terms of Business Phase

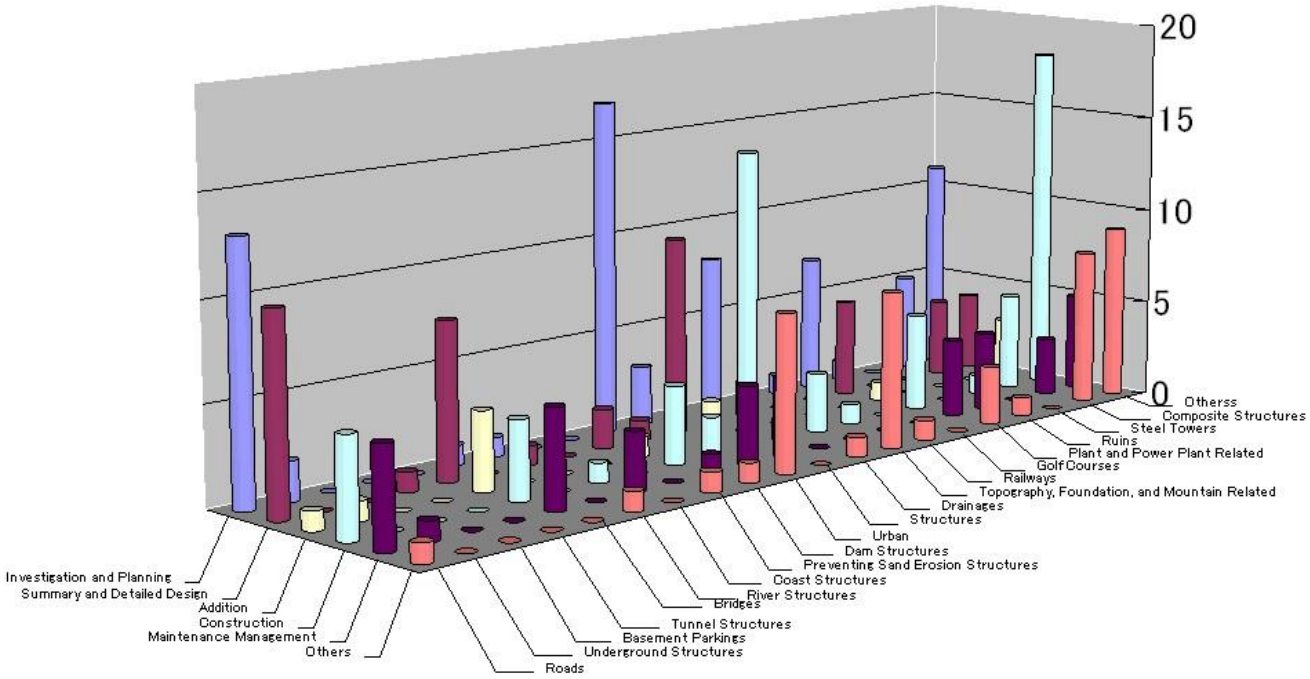

Fig.4 Number of Documents for Each Category of Construction Field / Business Phase

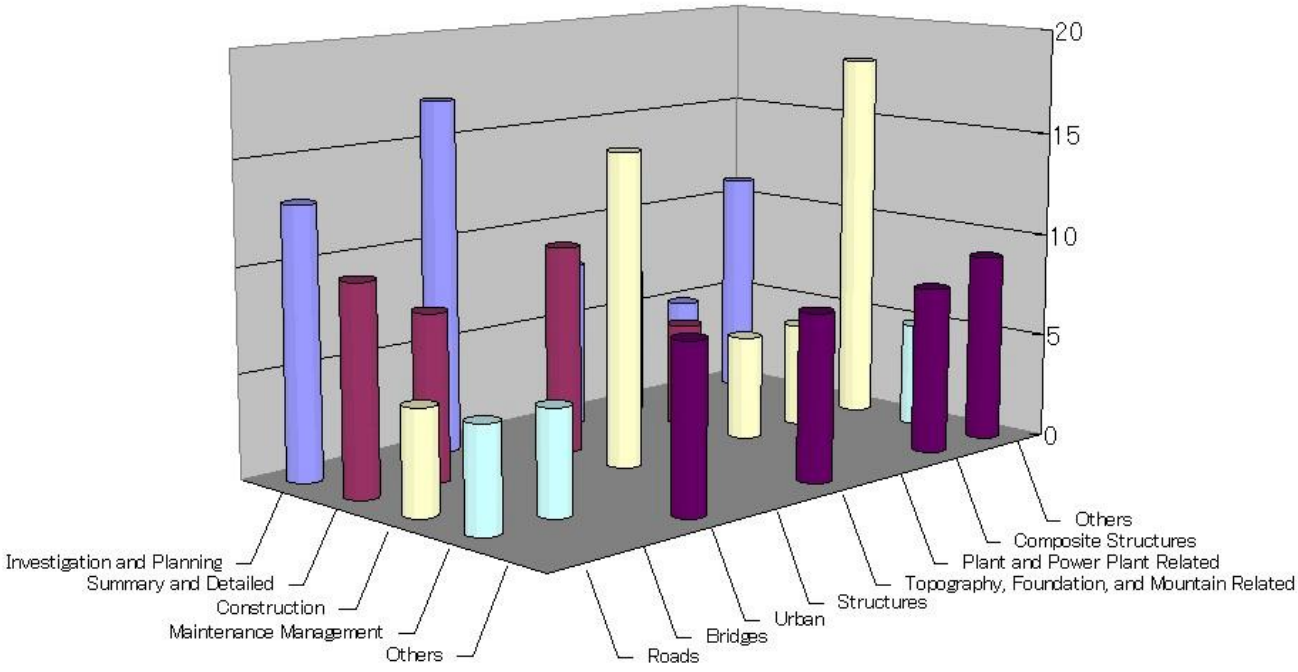

Fig.5 Number of Documents on Each Category of Construction Field / Business Phase (More Than 5 Counts)

counts.

This result shows the same trend as (1) analysis of number of documents in terms of business phase and (2) analysis of number of documents in terms of construction field. Particular result of this analysis that should be noted is that there is much use of 3D information in disaster prevention. In terms of ranking with the number of documents, it can be seen that "urban / disaster prevention" with 8 document counts is in 7th place, and "topography, foundation, and mountain related / disaster prevention" and "composite structures / disaster prevention" are both in 10th place with 6 document counts. From this, it can be understood that disaster prevention in the construction field is regarded as important, and the 3D information is used.

For the development of Construction CALS/EC in the future, it is believe that promotion of the use of 3D information is important, based on the fact that the utilization of 3D information is progressing in construction field / business phase.

5. Analysis of Keyword Frequencies in Terms of Construction Field / Business Phase

Keywords of the document were sorted in terms of construct field / business phase, for the purpose of determining keyword that is highly related to each category. Also, the keyword frequency analysis was performed on the categories with more than 5 document counts. From the group of frequency-analyzed keywords, those that have frequency below 20% were excluded from the analysis. By using the above method, a table that shows the keyword frequency of each category was produced, as shown in **Table 3**. Characteristics of each category were studied with keyword frequencies.

(1) Roads / Investigation and Planning [A1]

The characteristic of this category is that it has high frequency of the keyword "CALS/EC" and "Life cycle". From this, it can be speculated that promotion of construction CALS/EC is progressing in this category. Also, by the fact that there are many keywords such as "photogrammetry", "digital image", and "aerial photo", it can be understood that aerial photographs and digital images are being used for photogrammetry.

(2) Roads / Summary and Detailed Design [A2]

Frequency of the keyword "CG" is extremely high in this category. By examining the documents in the category, it can be seen that CG are being used to provide visual presentation of the road plans for the residents. It is believed that the use of CAD and CG in the construction industry is essential for explaining construction plans to the residents.

(3) Roads / Construction [A4]

In this category, it can be seen that there are a lot of cases of use of 3D information in expressways, as there is keyword "highway" on all of the documents. Because there are a lot of keywords of "soil filling" and "cut / fill volume", it can be suspected that 3D information is effectively used in calculation and management of cut / fill volume in the highway construction business.

(4) Bridges / Summary and Detailed Design [E2]

In this category, there are a lot of keywords, such as "structural design", "reinforced concrete structures", and "steel structures", which are related to bridges. From the existence of keywords such as "product model" and "modeling", it can be said that 3D information is used in bridge modeling.

(5) Urban / Investigation and Planning [J1]

In this category, keywords such as "CG", "urban view", "simulation", and "virtual reality" have the highest frequencies among the group. From this, it can be thought that visualization of urban plans is being performed by expressing them in CG and by using simulation and virtual reality.

(6) Urban / Disaster Prevention [J9]

In this category, keywords related to disaster prevention held the top ranks. From the fact that there is keyword of "simulation", it can be understood that 3D simulation of disaster prevention is being performed. Also, because there are a lot of keywords that are related to ground conditions and earthquakes, it can be understood that there are great deal of emphasis especially on earthquakes, among the field of disaster prevention.

(7) Structures / Summary and Detailed Design [K2]

In this category, because there is keyword of "2D", it can be said that system that integrated 2D / 3D is being used. It can also be thought that CG modeling is being used in structural design phase.

Table 3 Keyword Frequencies

Roads/Investigation and Planning [A1]		Topography, Foundation, and Mountain related/Investigation and Planning [M1	
Road plannig	46%	CG	50%
CALS/EC	31%	DTM	38%
CG	31%	Image	38%
Life cycle	31%	DEM	25%
Photogrammetry	31%	Simulation	25%
Topographical map	31%	Modeling	25%
Road construction	31%	Remote sensing	25%
Road design	31%	Numeric altitude model	25%
DTM	23%	Topographic survey	25%
Database	23%	Topography, Foundation, and Mountain Related/Disaster Prevention [M9]	
Digital image	23%	Land development	50%
Aerial photo	23%	Numerical analysis	33%
Topographic survey	23%	Topographical map	33%
Calculation of amount of soil	23%	Geologic structure	33%
Contour line	23%	Earthquake movement	33%
Roads/Summary and Detailed Design [A2]		Earthquake disaster prevention	33%
CG	70%	Disaster measures	33%
Road construction	60%	Plant and Power Plant Related/Investigation and Planning [P1]	
Road design	50%	Product model	43%
2D	40%	Modeling	43%
CALS/EC	30%	CG	29%
Database	30%	Nuclear power structure	29%
Measurement	30%	Geographical features	29%
Topographical map	30%	Layout planning	29%
Roads/Construction [A4]		Plant and Power Plant/Summary and Detailed Design [P2]	
Highway	100%	Database	40%
GPS	40%	Pipeline design	40%
Soil filling	40%	Plant and Power Plants/Construction [P4]	
cut/fill volume	40%	Simulation	60%
Bridges/Summary and Detailed Design [E2]		Virtual reality	60%
Structural design	50%	Construction planning	60%
Detailed design	50%	Construction site	60%
Detailed drawing	38%	Environment	40%
Reinforced concrete structures	38%	Construction machinery	40%
Distribution bones	38%	Assembly industrial method	40%
CG	25%	Underground power plant	40%
Product model	25%	Composite Structures/Investigation and Planning [S1]	
Modeling	25%	Photogrammetry	40%
Steel structures	25%	Topographical map	40%
Material	25%	Map production	40%
Urban/Investigation and Planning [J1]		Composite Structures/Construction [S4]	
CG	53%	GPS	40%
Urban view	53%	Laser scanners	40%
Simulation	41%	Construction work	40%
Virtual reality	29%	Composite Structures/Disaster Prevention [S9]	
Building	29%	Underground structures	50%
Modeling	24%	Simulation	33%
Urban	24%	Modeling	33%
Photogrammetry	24%	Analysis	33%
Urban model	24%	Sai photograph	33%
Urban/Disaster Prevention [J9]		Topographical map	33%
Urban disaster prevention	63%	Geologic structure	33%
Disaster prevention planning	38%	Ground survey	33%
Simulation	25%	Collapse risk	33%
Building	25%	Others/Investigation and Planning [T1]	
Measurement	25%	Digital image	45%
Geologic structure	25%	Photogrammetry	36%
Geologic map	25%	Map production	36%
Seismic observation	25%	CG	27%
Seismic prospecting	25%	Others/Construction [T4]	
Earthquake disaster prevention	25%	Simulation	33%
Urban planning	25%	CALS/EC	28%
Absorption projection technology	25%	CG	28%
Structures/Summary and Detailed Design [K2]		Construction work	28%
Building design	100%	GPS	22%
2D	40%	Animation	22%
CG	30%	Construction site	22%
Product model	30%	Quality control	22%
Structures [K4]		Others/Lifecycle [T10]	
Structural construction	40%	Virtual reality	80%
Construction planning	40%	CG	60%
HPC industrial method	33%	Life cycle	60%
Building design	33%	Database	40%
		Structure	40%

（8）Structures [K4]

In this category, it can be recognized that 3D information is being effectively used in construction of structures, because there are keywords of “structural construction” and “construction planning”. Also, presence of the keyword “building design” shows that 3D information is being used in building design.

（9）Topography, Foundation, and Mountain related / Investigation and Planning [M1]

In this category, frequencies are high in keywords such as “CG” and “DTM”. From this, it can be understood that investigation and planning are being executed by using CD and DTM, in the field related to topography, foundation, and mountain. It can also be stated that utilization of remote sensing technology is expanding.

（10）Topography, Foundation, and Mountain Related / Disaster Prevention [M9]

In this category, because the keyword “land development” is found in half of the documents, it can be understood that 3D information is being used in land development with consideration of disaster prevention. Also, from the fact that there are a lot of keywords related to earthquakes, it can be speculated that there is high interest especially in earthquakes in this category.

（11）Plant and Power Plant Related / Investigation and Planning [P1]

In this category, because frequencies are high on keywords such as “product model” and “modeling”, it can be understood that 3D information is being used in modeling in plant / power plant related work. Because plant / power plant is complicated structure, it is thought that 3D expression is in demand.

(12) Plant and Power Plant / Summary and Detailed Design [P2]

In this category, there are keywords “database” and “pipeline design”, and it can be understood that the use of database is advancing. Also, it can be suspected that 3D information is especially used in pipeline design.

(13) Plant and Power Plants / Construction [P4]

In this category, frequencies of keywords “simulation” and “virtual reality” are high. From this, it can be said that visualization of construction of plant and power plant is being performed by using simulation and virtual reality.

(14) Composite Structures / Investigation and Planning [S1]

In this category, there are keywords “photogrammetry”, “topographical map”, and “map production”. From this, it can be understood that photogrammetry is being used in topographical map and in map production.

(15) Composite Structures / Construction [S4]

Because there are keywords “GPS” and “laser scanners”, it can be understood that construction of 3D information is being performed by using GPS and laser scanner in construction of composite structures.

(16) Composite Structures / Disaster Prevention [S9]

In this category, “underground structures” is the keyword for half of the documents. From this, it can be said that 3D information is being used in expression of extremely graphically complicated underground structures. It can also be said that 3D disaster prevention simulation is being performed.

(17) Others / Investigation and Planning [T1]

In this category, because there are keywords “digital image”, “photgrammetry”, and “CG”, it can be known that digital image acquired from photogrammetry is being expressed in 3D in investigation / planning phase.

(18) Others / Construction [T4]

In this category, frequencies are high in keywords of “simulation” and “CG”, and it can be known that simulation is being performed by using CG in the construction phase. In addition, from the keyword “animation”, it can be thought that 3D CG is being expressed as an animation.

(19) Others / Lifecycle [T10]

In this category, because frequencies are high in keywords such as “virtual reality” and “CG”, it can be understood that technology in each of the lifecycle field is gaining attention. From this, it can be thought that in lifecycle process, information for exchange, collaboration, sharing, and reuse is being transformed three- dimensionally.

6. Consideration

In this research, documents related to the application of 3D information in the construction industry were investigated. Keywords were extracted from 282 documents. In addition, documents were classified in terms of construction field and business phase based on the keywords.

To the classified documents, “analysis of number of documents in terms of construction field / business phase” and “keyword frequency analysis in terms of construction field / business phase” were performed.

In “analysis of number of documents in terms of construction field / business phase”, 3 types of analysis were performed: “analysis of number of documents in terms of construction field”, “analysis of number of documents in terms of business phase”, and “analysis of number of documents in terms of construction field / business phase”.

In these 3 types of analyses, we were able to grasp the current circumstance of practical application of 3D information in the construction industry. In construction field and business phase that use 3D information, it can be thought that process of construction CALS/EC is being assertively implemented. It is believed that in the future, information exchange, collaboration, sharing, and reuse of entire life-cycle will be smoothly proceeded by continuous use of 3D information in each construction field and business phase.

In “analysis of keyword frequencies in terms of construction field / business phase”, analysis of keyword frequencies in each category was performed. By analyzing keyword frequencies, we were able to grasp the type of technology and the field that the 3D information is being used for each construction field and business phase.

7. Conclusion

In order to develop the construction industry for the next generation, it will be important to effectively utilize 3D information. In this research, document investigation was performed in order to grasp the current situation on practical application of 3D information in the construction industry.

From this present research, construction fields and business phases in which 3D information is being used were clearly expressed on charts and diagrams. In addition, by analyzing keyword frequency for each document, we were able to grasp how the 3D information was being used.

Result of this present research is believed to be an extremely useful information for engineers and technologists who are attempting to apply 3D information for introduction of construction CALS/EC. In the future, by periodically performing the document investigation in the same way, we would like to grasp the expansion of the use of 3D information. In addition, we would like to contrive development that will further make this research a better use for the professionals in the construction industry.

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