A Study on the indoor air quality management effect of intelligent building certification drogram

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ABSTRACT

The management of indoor air quality is accomplished by various types of complex mechanisms related to indoor environment and recently, an integrated solution applying state of art technology is being presented pertaining to the management of indoor air quality.
Currently in Korea, an intelligent type certification program is developed and enforced. This research has looked into the indoor air quality management effect while applying the intelligent building certification program which is being enforced at this time has been applied to buildings through simulation.
The indoor air quality simulations used in this research are TRNSYS16, TRNFLOW and IA-QUEST.
Through the result of this research, the effect of intelligent building certification program on indoor quality management of the building can be found out while an elaborate system evaluating the relationship between such indoor air quality management and other influence factors becomes necessary.

1. INTRODUCTION

Recently in Korea, the interest toward high standard information communication technology and quality of indoor environment as well as the use of economical energy has increased while the interest toward the intelligent building(IB) that can apply these things integration has increased. Accordingly, the Ministry of Construction and Transportation(MOCT) of Korea has imported the Intelligent Building Certification Program(IBCP) to lead and promote IB. While the IBCP of Korea at this time is limited to office, it is expected to gradually extended and operated at apartments, commercial buildings and so on. Accordingly, the purpose of this research is to find out the intelligent building certification system in general which is being enforced in the country and to perform quantitative analysis on the effect of essential, evaluation and additional categories by each field for certification of class toward indoor air quality through simulation.

2. INTELLIGENT BUILDING CERTIFICATION PROGRAM

2.1 Intelligent building

The IB could be called the one that can create new space culture and in which a quick and stable information services are achieved through safety and extensibility of each system as the pleasant environment is provided by importing various systems that are appropriate for the size, purpose and function of the building in order to cope with the 21st century knowledge based society and maximize the productivity of work as the economic management of the building is enabled by cutting down the energy.

2.2 Introduction of Certification Program

The Intelligent Building Certification Program provides objective information on intelligence level of the building, raise technological and economical values on IB as the initial investors, constructors, owners, managers and users easily grasp the level of IB as well as giving social and functional roles of IB by coping with knowledge based society.

2.3 Fields and Details of Evaluation

(1) Evaluation Items

For evaluation fields and details of IBCP, the certification class is classified systematically according to detailed enforcement guideline. It is classified into a total of six specialized fields called Architectural Environment and Design(AED), Mechanical System(MS), Electrical System(ES), Information and Communication System(ICS), System Integration(SI) and Facility Management(FM) while classified as required, appraisal and bonus items. The entire fields are classified into 124 sub-items.

(2) Evaluation Details

The evaluation item is evaluated by classifying into required, appraisal and bonus items. The evaluation details by each item are as follows.

Required item(RI) : As an item which must be basically prepared, the subject is excluded from score calculation. And the evaluation itself becomes impossible in case even one category couldn't be satisfied.

Appraisal item(AI) : As an item which receives a score by scoring table according to the evaluation standard, it is evaluated by applying weight for each item.
Bonus item(BI) : As an item giving bonus score in case a specific intelligent technology has been applied, the bonus score is granted.
(3) Scoring Criteria for Each Field

Table 1: organization

Classification	RI	AI	BI	sum
AED	4	10	6	20
MS	5	10	7	22
ES	6	11	6	23
ICS	3	15	7	25
SI	3	9	4	16
FM	4	10	4	18
sum	25	65	34	124

The total score is 650 points. For scores of each field, only the ICS field is 150 points and the remaining 5 fields are 100 points. The 65 points which is 10% of total point is to be received as bonus in case of satisfying the bonus item.
(4) Certification Class

Table 2: criteria of assessment

Classification	Appraisal point	Bonus point
AED	100	10
MS	100	10
ES	100	10
ICS	150	15
SI	100	10
FM	100	10
sum	650	65
appraisal point + bonus point = 750		

The grade for certification is classified as 1st grade, 2nd grade and 3rd grade. If the score distribution for each field isn't satisfied(1st grade: 80% the under, 2nd grade: 70% the under, 3rd grade: under the 60%), the subject failure of is applied and unable to receive the certification grade.

3. CATEGORY ANALYSIS

Table 3: rating and point

rating	point	remarks
1st grade	above 90%	Point 650(100%) 1st grade:585 2st grade:525 3st grade:455
2st grade	below 90%, above 80%	
3st grade	below 8%, above 70%	

3.1 Criteria for analyzing categories related to indoor air quality

First, as an analysis related to indoor air quality, the analysis was performed by classifying into three main categories.

3.2 Degree of influence by fields

Table 4: Analysis standard

Category	Contents
A	Has direct influence on IAQ, can quantitative IAQ
B	Has direct influence on IAQ, can qualitative IAQ
C	Has indirect influence on IAQ

3.2.1 The field of architectural environment and design

In the field of architectural design and environment, 8 categories among a total of 20 categories had influence on indoor air quality. The indoor finish and space organization, etc mainly act as factors.

3.2.2 The field of Mechanical System

Table 5: The influence of AED

Classification		Evaluation items	I	P
RI	energy saving and sustainable	Using environmental friendly materials	A	-
	comfortable	Sound	C	-
AI	plane plan	Occupation area for one person	A	10
	section plan	Ceiling height	A	10
	building envelope	Facility to prevent sunlight	B	15
BI	fire	Refuge plan	C	2
	design	remodeling	B	2
	the others	gardening	C	1
I: influence, P: point				

In the field of MS, 10 items among a total of 22 items were derived as subjects. For analysis factors, they're organized as items that are necessary for cooling and heating equipments of the building.

3.2.3 The field of Electrical System

In the field of ES, only 1 items among a total of 23 items was derived. It is an analysis factor that has considered safe operation of cooling and healing equipments by ensuring emergency power source during the outbreak of emergency situations.

3.2.4 The field of Information Communication System

In the field of ICS, the category which influences the indoor air quality hasn't been derived. This is the result of category organization which mainly evaluates the network of system due to the nature of information communication.

3.2.5 The field of SI

Table 6: The influence of MS

Classification		Evaluation items	I	P
RI	Heat source facility	Selection of heat source facility	B	-
	Air conditioning facility	Zoning of air conditioning and ventilation	A	-
AI	Air conditioning facility	Items of air conditioning	A	10
		Zoning air conditioning	A	15
		Method of air conditioning	A	15
		Amount of introducing outer air	A	5
	Control facility	EMS	B	5
BI	Heat source facility	Renewable energy system	C	2
	Air conditioning facility	Building envelope for energy saving	B	2
	materials	Using environmental friendly materials	A	2
I: influence P: point				

Table 7: The influence of ES

Classification		Evaluation items	I	P
RI	Power supply facility	Emergency power	A	-
I: influence, P: point				

In the field of SI, 3 items among a total of 16 categories have been derived and consisted of items through integration and monitoring of cooling and heating system in buildings.

3.2.6 The field of Facility Management

In the field of FM, 7 items among a total of 18 items have been derived and consisted of system maintenance items such as cooling and heating system in buildings just like the SI field while being organized as indirect influence of details such as existence of that management organization and placement of the manual, etc.

Table 8: The field of SI

Classification		Evaluation items	I	P
RI	Monitoring controlling of integrated	integrated a wealthy system	B	15
	Inter-locking of integrated	inter-locking secenario for service backup	B	10
	Information analysis of integrated	Automatically collection of operation information and energy usage	C	15
I: influence, P: point				

Table 9: The field of FM

Classification		Evaluation items	I	P
RI	Facility management organization	Existence and non-existence of FMO	C	-
	Manual for maintenance	Preparing manuals for maintenance	B	-
AI	FMO and work	The level of member of FMO	C	5
	Function of FMS	Multiplicity of constructed function	C	10
	Facility management work and manual	The level of manual for FMO	C	5
BI	Facility management work	Construction of manual database	C	3
		Management standard	C	2
I: influence, P: point				

3.3 Indoor air quality influence score distribution of entire field

<Table 10> is the one that has put together the influence of each field and for the influence related to indoor air quality, 29 items among a total of 124 items and 161 points among a total of 750 points is shown as having influence.

Table 10: Influence and point of total

Field	Classification	standard			
		A	B	C	sum
AED	influence,	3	2	3	8
	point	20	17	3	40
MS	influence,	6	3	1	10
	point	47	7	2	56
ES	influence,	1	-	-	1
	point	-	-	-	-
ICS	influence,	-	-	-	-
	point	-	-	-	-

SI	influence,	-	2	1	3
	point	-	25	15	40
FM	influence,	-	1	6	7
	point	-	-	25	25
sum	influence,	10	8	11	29
	point	67	49	45	161

3.4 Highest and lowest points by fields

The highest and lowest points of class evaluation standard followed by influence of each category have been classified to be shown in the following <Table 11~13>.

3.5 Standard for applied score of the item by grades

<Table 14> is the one that has calculated and shown applied scores by each certification program class using derived items. Here, the basic applied items have been equally applied for 1st, 2nd and 3rd grade while classifying the class by reflecting the highest and lowest scores by derived items

Table 11 : Highest and Lowest of influence A

Field	Evaluation items	HP	LP
ADE	Using environmental friendly materials	-	-
	Occupation area for one person	10	4
	Ceiling height	10	4
MS	Zoning of air conditioning and ventilation	-	-
	Items of air conditioning	10	4
	Zoning air conditioning	15	6
	Method of air conditioning	15	6
	Amount of introducing outer air	5	2
	Using environmental friendly materials	2	-
ES	Emergency power	-	-
ICS	-	-	-
SI	-	-	-
FM	-	-	-
Sum	67	26	
HP : Highest point, LP : Lowest point			

Table 12 : Highest and Lowest of influence B

Field	Evaluation items	HP	LP
ADE	Facility to prevent sunlight	15	6
	Remodeling	2	-
MS	Selection of heat source facility	-	-
	EMS	5	2
	Building envelope for energy saving	2	-
ES	-	-	-
ICS	-	-	-
SI	Integrated a wealthy system	-	-
	Inter-locking secenario for service backup	10	4
FM	Preparing manuals for maintenance	-	-
Sum	34	12	
HP : Highest point, LP : Lowest point			

Table 13 : Highest and Lowest of influence C

Field	Evaluation items	HP	LP
ADE	Sound	-	-
	Refuge plan	2	-
	gardening	1	-
MS	Renewable energy system	2	-
ES	-	-	-
ICS	-	-	-
SI	Automatically collection of operation information and energy usage	15	6
FM	Existence and non-existence of FMO	-	-
	The level of member of FMO	5	2
	Multiplicity of constructed function	10	4
	The level of manual for FMO	5	2
	Construction of manual database	3	-
	Management standard	2	-
sum	40	14	
HP : Highest point, LP : Lowest point			

For the simulation related to influence of indoor air quality, the standard building model has been set to start with and its setup conditions are like <Table 15>.

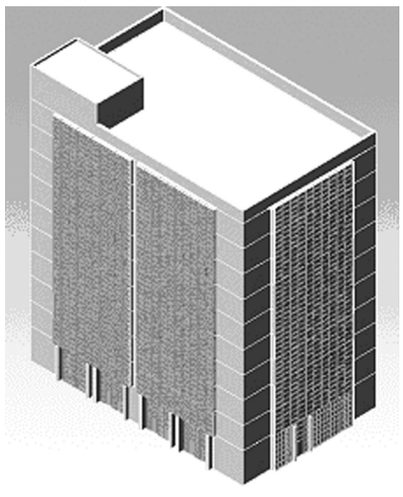

Figure 1: 3D of standard building

[Figure 1] and <Table 16> are the ones that have been modeled by the standard building model setup criteria and is a model with scale of 10 floors above ground.

Table 14 : The Standard of Acquirement per Grade

Grade	Standard	Acquirement
1st	585	596
2nd	525	529
3rd	455	455
* 1st : 3rd Grade+ highest score of A,B and C * 2nd : 3rd Grade+ highest score of B and C * 3rd : Include of lowest score of A,B and C		

Table 15 : PM Criteria

Classification	Standard	Remark
Type	Office	Buildings for business that has standard floor
Place	Seoul or Metropolitan area	The area in the country where many buildings are being erected
Area	3,300~33,000m2	Subject of certification for super high-way information and communication
Story	5~10 stories	Height for typical floors of 4~6 stories to exist at least
Form of Plane	Square or Rectangular	Minimizes effect from external factors

Table 16 : Outline of PM

Classification	Outline
Type/ Place	Office/ Seoul
Area	9,357.94m2
Story	2 stories below and ten above the ground
Form of Plane	Rectangular
Direction	South
Structure	Curtain-wall and ferroconcrete

3.6 Simulation analysis

For the carbon dioxide density, the TRNSYS 16 and TRNFLOW that are detailed programs for building interpretation were used. The climate factor is composed as a total of 11 like <Table 17>as the hourly mean value of Seoul area provided by Korea Meteorological Administration. Among these, the outer temperature and solar radiation which has the most influence on building load were shown in summary.

Table 17 : Meteorological Element

No.	Classification	Unit
1	Sky Diffuse radiation	kJ/m^2
2	Dry Bulb Temperature	°C
3	Beam Radiation	kJ/m^2
4	Wind Direction	0~360°
5	Velocity	m/s
6	Relative Humidity	%
7	Radiation	kJ/m^2
8	Atmosphere Beam Radiation	kJ/m^2
9	Cloud cover	1~8
10	Ground temperature(1.0m)	°C
11	Atmosphere Pressure	ps

TVOCs is the thing that can predict the discharge and indoor density of contaminants followed by installation of construction materials within a single zone. The analysis has been performed using IA-Quest of Canada NRC which enables the analysis of result by entering installation time, ventilation and schedule, etc by providing discharge feature database of about 90 types of VOC's in total.

Among various types of contamination sources created indoors, (microscopic dust, carbon dioxide, formaldehyde, radon, carbon monoxide, nitrogen dioxide, TBC, asbestos, volatile organic compound and ozone, etc) the simulation analysis on carbon dioxide and volatile organic compound have been performed in this thesis.

The pollutant concentration is defined as

$$c = \frac{m_p}{m_a}$$

Where

m_p = mass of pollutant in a certain volume of polluted air (kg)

m_a = mass of dry and clean air in the same volume of polluted air(kg)

Mass balance for pollutant p in zone i :

$$\frac{dm_{pi}}{dt} = \sum_{j=0}^{NZ}\sum_{k=0}^{ZK_i}(1-\eta_{jik})\dot{m}_{pjik} - \sum_{j=0}^{NZ}\sum_{k=0}^{ZK_i}\dot{m}_{pjik} - k_p \bullet m_{pi} + S_{pi}$$

Where :

m_{pi} = Total mass of pollutant p in zone i(kg)

$\dot{m}_{pjik}$ = Total mass flow of pollutant p from zone j to zone i through link k(kg/s)

k_p = Decay constant of pollutant p(1/s)

S_{pi} = Source of pollutant p in zone i(kg/s)

η_{jik} = Filter efficiency of link k between zone j and i

NZ = Number of zones

NK = Number of links

3.6.1 Carbon dioxide analysis

[Figure 2] has analyzed the carbon dioxide density of indoors according to indoor area occupied per 1 person. The carbon dioxide density was set as about 200ml/min per person which is a room and room occupancy area has been analyzed with 4 types of 10, 8, 6 and 4m2. As the area of the room occupied per person became lower, the carbon dioxide density of indoors showed an increasing trend like the figure, this had high initial carbon dioxide density due to increased number of people in the room and the density has shown a continuous increasing tendency due to increase of amount generated per 1 person.

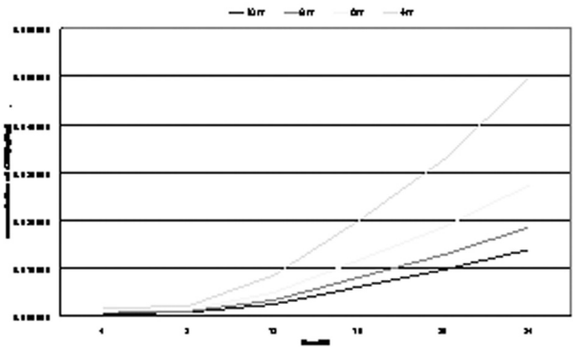

Figure 2: **Indoor area concentration of co_2**

[Figure 3] is the one that has analyzed the influence from ceiling height with same conditions as the analysis on occupied area per 1 person and analyzed in 1m intervals from 2.8m~2.5m.

As the result of difference in height of the ceiling, although the difference of density between height intervals was low, we could see that the carbon dioxide density of the room increases by low distribution as the height of ceiling becomes higher.

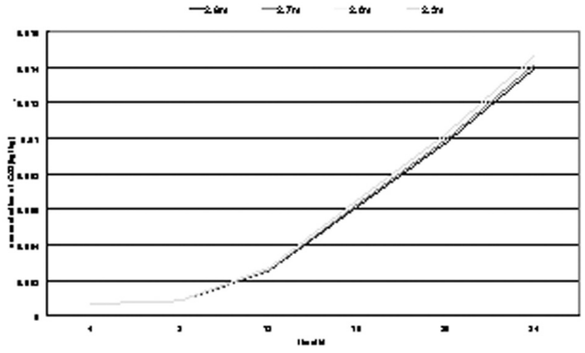

Figure 3: **Ceiling height concentration of co_2**

3.6.2 Volatile organic compound analysis

The density of TVOCs has been analyzed using IAQUEST.

Table 18 : Density of TVOCs

CMH	Area rating of application sustainable materials				
	80%	70%	60%	50%	40%
20	1.32	1.99	2.65	3.31	3.97
25	1.13	1.70	2.27	2.84	3.40
30	1.01	1.51	2.02	2.52	3.02
35	0.92	1.37	1.83	2.29	2.75
40	0.84	1.26	1.69	2.11	2.53
Unit L mg/m^3 year					

<Table 18> is the annual average density value followed by applied space of eco-friendly materials and amount of incoming outside air. The density of TVOCs has decreased as the area of eco-friendly material usage has increased. Also at this time, the density has decreased as the incoming amount is increased by interference of incoming outside air.

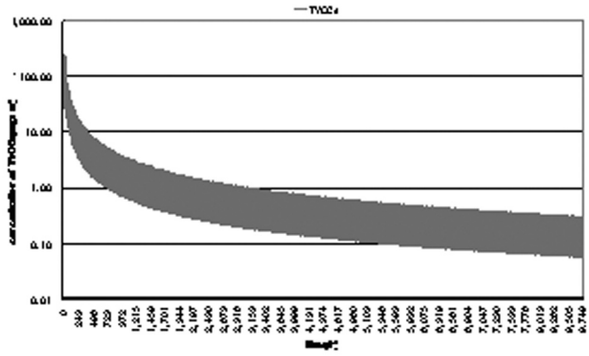

Figure 4: **Concentration of $TVOC_s$**

[Figure 4] is the annual density value of TVOCs when the ratio of eco-friendly material usage is 60% and amount of incoming outside air is 30CMH. As the result of assuming the amount of incoming outside air from 9-18 o'clock

as 30CMH and assuming as about 10% of incoming outside air afterwards, the density of TVOCs is being decreased in general as time passes by while the difference in density of day and night has changed by difference in the amount of incoming outside air due to schedule.

4. CONCLUSIONS

Among 29 items that have been derived, 10 items (34.5%) were shown as the field of mechanical system. Generally, the heat source required for cooling and heating which influence the indoor air quality and air conditioning facility were analyzed as most frequent factors. Also, the items that can be calculated quantitatively were shown as 10 items, the items that can be evaluated qualitatively were shown as 8 items and the items in which indirect influence can be evaluated were shown as 11 items. As a result of analysis on the effect of carbon dioxide and TVOCs, the carbon dioxide density showed a decreasing trend as the area of the room occupied per 1 person in the office has increased. We could confirm that the carbon dioxide density also decreases depending on the increase of ceiling height in the room.

Also, we could confirm the condition in which the density of TVOCs is decreased from the increased ratio of applying eco-friendly products, increase of applied space by amount of incoming outside air and increase of incoming outside air.

Therefore, the indoor air quality in office buildings can bring the improvement due to application of Intelligent Building Certification Program and also able to maintain a pleasant environment by moving up the class. Accordingly, the indoor air quality can be improved as even higher standard by applying more intelligent ventilation system and facility adjustment plan in office buildings.

REFERENCES

H.S. Lee(2007) " A study on the Intelligent Building Certification its effects on indoor air Quality and building energy,

IBS KOREA.(2006) "Handbook of the Intelligent Building Certification Program"

IBS KOREA. (2002) "Introduction to Intelligent Building System and Practices", Kidari Publications

J.S. Kim (2005), "Building Mechanic", SEOWOO Publications

Aesrl of Inha University(2004) "Analysis of Building Energy by TRNSYS", Kunkiyeon Publications

TRNSYS Manual