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NEW INTELLIGENT BUILDING INDEX FOR BUILDINGS AROUND THE WORLD – A QUANTITATIVE APPROACH IN BUILDING ASSESSMENT EXPERIENCE WITH HONG KONG TALLEST BUILDING, TWO INTERNATIONAL FINANCE CENTRE

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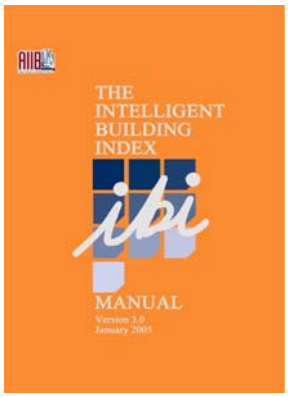
Summary

The, Intelligent Building Index (IBI) Manual version 3.0 which is the world first most comprehensive quantitative assessment method was published on 18 January 2005. The technical tool consists of 10 important constituting index modules (M) namely Green, Space, Comforts, Working Efficiency, Culture, High-tech Image, Safety & Structure, Management Practice & Security, Cost Effectiveness, and Health & Sanitation. Under the index modules, there are 378 constituting elements (x). The manual employs the concept of "Relative Importance" of each element (x) contributing to the corresponding module (M). The relative importance is reflected by the weighting (w) of the elements using the Cobb-Douglas function in calculation. The manual can be applied to audit various types of buildings but with different weight per module. The concept of relative importance or weight (Y) is used for each modules contributing to the overall IBI index (I).



In November 2004, the IBI 3.0 was used for the intelligent building audit for the 88-storey office building "Two International Finance Centre" in Hong Kong. The overall score is 95 which is the highest score so far audited by the IBI manual. The building is very strong in the areas of Working Efficiency, Cost Effectiveness, Space, Culture, and particularly outstanding in Management Practice & Security.

1. Introduction

The Intelligent Building Index (IBI) manual is developed by the Asian Institute of Intelligent Buildings (AIIB). AIIB is the first non-profit making organization in Asia committed to promoting public understanding and industry adoption of the principles and technologies of the intelligent buildings (IBs). The Institute was officially established in Hong Kong in 2000 and it has the following missions:

- ✧ To develop Asia's definition and standards for IBs.
- ✧ To act as an independent certification authority for IBs through the use of The Intelligent Buildings Index (The IBI).
- ✧ To educate and promote to the community benefits of IBs.
- ✧ To work with international counterparts to bring Asia up to date on developments related to IBs.

AIIB adopts an official definition of IB, "**An Intelligent Building is designed and constructed based on an appropriate selection of Quality Environment Modules to meet the User's Requirements by mapping with the appropriate building facilities to achieve a Long-Term Building Value**". Based on this official definition, AIIB is able to develop the world's first quantitative and comprehensive assessment method for an IB, called the IBI. All buildings can be assigned the IBI which is a score within the range from 1 to 100. "100" means that it is a perfect IB while "1" means that it is certainly a non-IB. The former IBI version 2 was published in 2001. In early 2005, the new version 3.0 is released in Asia with the adoption of some revisions to enable greater practicality and better presentation. It is the intention that the document will be used not only in Asia, but also in the US, Europe and all parts of the world.

The new IBI model consists of 10 **Modules (M)**, namely: Green, Space, Comfort, Working Efficiency, Culture, High-tech Image, Safety and Structure, Management Practice & Security, Cost Effectiveness, and Health & Sanitation. Within each module, there are various **Elements (x)**. The overall numbers of elements are 378. These elements are assessment criteria questions in 10 different building disciplines, namely, Architectural,

Structural, Building Services (Air-conditioning, Heating & Ventilation, Electrical & Building Management System, Fire, Lift & Escalators, Plumbing & Drainage), Acoustics, Environmental, and General.

1.1 History and Background of IBI Audit

The Asian Institute of Intelligent Buildings (AIIB) published her Intelligent Building Index (IBI) manual version 2.0 in October 2001. This IBI manual has been used as a tool to audit building intelligence since 2001. This manual had been employed in various Asian cities such as Singapore, Taipei, etc. in intelligent building auditing. In particular, the IBI manual had been selected as a study module in universities courses, such as Master of Science and some Diploma courses in Hong Kong. It has also been employed as a study reference guide in some tertiary education institutions in Singapore and Hong Kong.

Since 2002, AIIB has been awarding the "Building of the Year" to the most intelligent building in Hong Kong every year. The building which has the highest score in the IBI audit in a particular year will be awarded. So far, according to the auditing record, twenty two (22) buildings were audited in Asia using the IBI manual.

In 2002, AIIB gave an award to the Kadoorie Biological Sciences Building at the University of Hong Kong as the Building of the Year. The building is strong in the modules of high-tech image, comfort and space. The audit was based on IBI version 2.0.

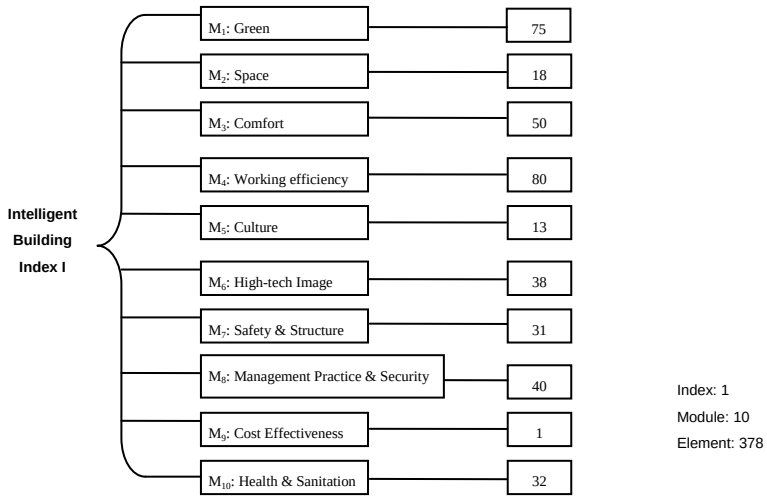
In 2003, the Hong Kong Science and Technology Park Phase I was awarded the Building of the Year by AIIB using the IBI version 2.0. The building is outstanding in the modules of working efficiency, cost effectiveness, high-tech image, comfort and green.

From March to May 2003, Hong Kong was seriously suffered from the attack of Severe Acute Respiratory Syndrome (SARS) virus. AIIB anticipated the need to introduce a new index module no. 10 "Health & Sanitation" in addition to the IBI version 2.0. The six-star residential estate, The Leighton Hill, was awarded the Distinction Award on Module 10 in 2003.

In 2004, AIIB awarded the Building of the Year to the 88-storey high Two International Finance Centre using the IBI version 3.0. The building is of excellent performance in modules of working efficiency, cost effectiveness, space, culture, management practice & security.

2. Intelligent Building Index

With reference to the previous sections, IBI consists of 10 Modules and 378 Elements. Please refer to the Figure 1, the IBI Model.



2.1 Weighting Concept in Elements and Modules

The 378 elements will be assessed for different intelligent buildings. Each element is an "assessment criteria question" and it is given a weight for its contribution to the module. The score of each element **x** is an integer from 1 (lowest score) to 100 (highest score). The weight is assigned from an integer range of 1 to 9. From the IBI manual, in some situations, the same element question occurs in 1 module and repeated in another module(s). This is normal. For example, Element no. 1.24 "Thermal comfort: Temperature and Relative Humidity" under the M1 "Green" module is of weight 5. The same element occurring in element no. 3.18 under the M3 "Comfort" module weighs 9, and that of element no. 4.16 under the M4 "Working Efficiency" weighs 8. From this, it is reflected their relative importance of an element contributing to different modules. It understandable that the "Temperature and Relative Humidity" score is more important in the

"Comfort" module of as it weighs 9, while it is relatively less important in the "Green" module since it weights only 5 there.

One may ask a question, "With the similar weighting concept, will different weightings be also applied to the contributions to different types of buildings?". The answer is definite. It is readily realized that each module will also have a different relative importance, or weightings, contributing to the overall IBI score for different types of buildings.

For example in a situation, if a hospital has all 10 module scores exactly the same as that for an office building, should the 2 buildings obtain the same scores for the overall intelligent building index (**I**)? From our intelligent judgment, the 2 building should have 2 different scores of **I**. It is readily understood that the module of "Working Efficiency" is more important in "Office Building", while the module of "Health & Sanitation" is more important in "Hospital". Therefore, the concept of weightings for each module corresponding to each "Types of Building" is readily established. Table A shows the weighting of modules for different types of buildings.

It is readily recognized that the concept of weightings, or relative importance, is required in the 2 stages of calculations:

- ✧ Calculation of the 10 Module scores (**M**) from Element score (**x**) using Element Weights (**w**); and
- ✧ Calculation of IBI score (**I**) from Module score (**M**) using the Module Weights (**Y**).

Table A: The module weightings, Y, for different types of buildings

Type of Building	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}
Commercial (office) Buildings	7	8.5	7.5	9	6	8.5	6.5	7	6	8
Hospitals	7	5	7	6	2	4	8	7.5	1	9
Residential Buildings	6.5	2	9	4	7	2	7	8	3	9
Hotels	4	6	9	5	4	7	6.5	8	3	8
Educational Institutions	7	8.5	6.5	9	8	5	6.5	6	4	8

2.2 Calculation Method

With the acceptance of the concept of weightings within the 10 Modules **M** and the Overall Index **I**, it is readily realized that the calculation is not a simple multiplication and summation.

The use of the"Cobb-Douglas" utility function is adopted by AIIB four years ago in the IBI version 2.0. The methodology employs the calculation of raising the power of the score with respect to the weightings. To calculate the Module Score **M**, the Cobb-Douglas function is to be used with respect to the Element Weightings **w** for each Element Score **x**. To enable the calculation of **I**, again Cobb-Douglas function is used with respect to the Module Score **M** and the Module Weightings **Y** designed for the type of buildings.

The following formulae are used for the calculation of 10 Module Score **M**, and subsequently the Overall IBI **I**.

$\mathbf{M}_1$ to $\mathbf{M}_{10}$ are calculated using the general formula **M**.

$$M_n = x_1^{\frac{w_1}{w_1+\ldots w_n}} \cdots x_n^{\frac{w_n}{w_1+\ldots w_n}}$$

…… **Formula M**

where $\mathbf{w}_1$ is the weight corresponding to $\mathbf{x}_1$,
$\mathbf{w}_n$ is the weight corresponding to $\mathbf{x}_n$.
n is the number of elements under module $\mathbf{M}_n$.

Note: If any element that is not applicable, the score x is reset to 1 and the corresponding weight w is reset to 0.

Having all the $\mathbf{M}_1$ to $\mathbf{M}_{10}$ calculated, the calculation of **I** employs the formula below.

$$I = M_1^{\frac{Y_1}{Y_1+...+Y_{10}}} \quad ... \quad M_{10}^{\frac{Y_{10}}{Y_1+...+Y_{10}}}$$

……**Formula I**

where $\mathbf{Y}_1$ is the weight corresponding to $\mathbf{M}_1$,
$\mathbf{Y}_{10}$ is the weight corresponding to $\mathbf{M}_{10}$.

Note: The weights Y_1 to Y_{10} depend on the type of building and can be found in the Table A above.

2.3 The Modules and Elements

The Module 1 "Green" consists of 75 Elements. This module includes the environmental friendly constituents in a building. The constituting elements can categorized in groups of Environmental, Lift & Escalators, Lavatories and Provisions of Appliances, Thermal Comfort, Electrical Services, Heating services, Ventilation and Air-conditioning, Lighting, Drainage, Waste Disposals, etc.

In Module 2, the "Space" Module includes groups of elements in Architectural Design, Carpark and Transportation, Flexibility in Internal Arrangements, Building Provisions, etc.

For the Module 3, "Comfort" Module consists of various groups of elements like Architectural Design, Lift, Lavatory and Provisions of Appliances, Thermal Comfort, Ventilation and Air-conditioning, Lighting, Access, Acoustics, Colour, Entertainment Facilities, etc.

The "Working Efficiency" module 4 includes various element groups in Architectural Design, Lift & Escalators, Lavatories and Provisions of Appliances, Thermal Comfort, Lighting, High Technology, Sign and Directory, Carpark and Transportation, Building Facilities, etc.

The Module 5 "Culture" is considered to be the "soft" side of an intelligent building. It is believed that the module consists of the most valuable elements and these elements have never been identified in any intelligent building assessment tools. The elements include Feng Shui, Entertainment Facilities, Privacy Requirements, Colours, Interior Decoration, Food and Beverage, External Landscape and View, Indoor Plants, Religious Facilitation, Culturally Based Interior design, Promotion Activity, etc.

The Module 6 "High-tech Image" has been interpreted for many years to be the only provision and/or criteria of an intelligent building. In the IBI manual, it only constitutes a module since there are 9 other modules to go with it. However, it weights high in an office building. The element groups are Broadband Internet, Electrical Services, Office Automation, Electronic Facilities, Artificial Intelligent Control, Webpage, Hotlines, Telephone Provisions, Fibre-optic Network, Building Services Automation, Mobile Phone Coverage, Advanced Carpark Facilities, etc.

The "Safety and Structure" module 7 consists of various important parameter elements in an intelligent building. The elements include Earthquake Monitoring, Building Structural Condition Survey, Structural Monitoring, Tile Debonding Monitoring, Terrorist Attack Precaution Plan, Fire Protection, Electrical Safety, Elevator Reliability, Public Announcement, Total Egress, Escape Plan, Essential Electrical Power, Preventive Maintenance of Building Systems, Indoor Air Quality, Safety Management System, Settlement Monitoring, Risk Management, Security and Crowd Control, etc.

The Module 8 of "Management Practice and Security" indicates some very important parameters for successful implementation criteria of an intelligent building. A truly intelligent building must require a very good building management to operate and maintain. The essential element groups are Building Management Practice, Building Services Operation and Maintenance, High Technology, Security and Monitoring, Controls, Management Planning, Water Supply and Drainage, Environmental Protection, etc.

The Module 9 "Cost Effectiveness" consists only 1 formula to calculate the life cycle costing of a building.The last Module 10 "Health and Sanitation" is one independent module that can be used separately to examine a building as a measurement tool for healthy buildings. It is particularly popular for residential building assessment. The element groups includes Potable and Flushing Water System, Drainage, Toilet, Carpark and Lift Ventilation, Odour, Cleanliness, Refuse Handling, Pest and Mosquitoes Controls, Filtration in Swimming Pools, Jacuzzi and Sauna, etc.

2.4 The Calculation Tool

The complete calculation is best to be carried out by computer. By making use of computer software of spreadsheet, e.g. Excel, the whole calculation can be done systematically. Furthermore, the sensitivity of each element contributing to each module can be easily identified.

3. Two International Finance Centre (2 IFC)

An intelligent a building assessment was carried out in November 2004 using the new IBI manual V3.0 for the most significant building in Hong Kong. This building is the 88-storey Two International Finance Centre at Central District. The building has many outstanding design features and the major building provisions are highlighted as follows.

Photo 1: Two International Finance Centre

Development:

- Two IFC has 2,000,000 sq. ft. area development.
- Total development including One IFC 785,000 sq. ft., IFC Mall 800,000 sq. ft., Four Seasons Hotel 800,000 sq. ft., Public Open Space 140,000 sq. ft., Total Car Parks 1,800.
- Integrated with Underground Lines: Airport Express and Tung Chung lines.

Structure:

- Building height of 420 metres.
- Central concrete core with 8 external mega columns.
- Foundation of 61.5 m diameter, 38 m deep cofferdam.
- Floor loading up to 10kPa.
- Design wind load of mean wind speed of 230 km/h, highest typhoon in the world.

Office Space:

- Extra high ceiling height of 3.3 m for trading floors with 340mm raised floor space.
- 2.7 m typical office floor with 190mm raised floor space.
- 15 m core wall to window depth.

Fire:

- Horizontal fire separation at 4 refuge floors of 7^{th}, 32^{nd}, 52^{nd} and 64^{th} floor with 20 escape staircases.
- 2 fully fire-protected “fireman lifts” serving all floors.

Lift:

- 42 high speed passenger lifts up to 6 m/s.
- 8 double deck shuttle lifts at 8 m/s and 6 double deck shuttle lifts at 6 m/s.
- 3 service lifts of 4,000 kg up to 8 m/s and 2 car park lifts.
- 2 executive express lifts.

Air Conditioning:

- Variable Air Volume (VAV) system with VAV box Direct Digital Control (DDC) on heating and cooling.
- Two air handling units per floor with interconnecting ductwork.
- Overall thermal transfer value (OTTV) at 24 W/sq.m. better than 35 W/sq.m. required.
- 10 numbers of 980 RT seawater cooled chillers.
- 8 numbers 320 RT air-cooled chillers, backed up by emergency generators, located on 9 mechanical floors for essential cooling.
- 24-hour chilled water supply at 17 W/sq.m. for office floor and 51 W/sq.m. for trading floor.

Electrical & Telecommunication:

- Dual feed power company incoming power supply with 48,300 kVA capacity.
- 17 numbers of standby generators of capacity from 800 to 1,800 kVA for fire fighting and tenant use.

- Fibre-optic cables for tenants.
- More than 30,000 pairs of Cat. 5 copper and 1,000 core fibre-optics.

3.1 Audit Result

The Two IFC was audited and has the overall Intelligent Building Index (IBI) at a score 95.06%. The breakdown of module scores is given in Table B.

Table B: Module Score of Two IFC

M1 – Green	93.28
M2 – Space	96.39
M3 – Comfort	91.42
M4 – Working Efficiency	97.00
M5 – Culture	95.31
M6 – High-tech Image	94.78
M7 – Safety & Structure	94.76
M8 – Management Practice & Security	96.66
M9 – Life Cycle Costing	96.00
M10 – Health & Sanitation	94.84
Overall IBI Score	**95.06**

Apart from the outstanding building design features described above, there are other special provisions from the building worth further illustrations. They are given extra bonus points in the audit process. These features are:

- Smart Card Access System
- Face Recognition System for Access Control
- X-ray checking machine and post office
- Trained dog for guarding and dangerous goods detection
- Anti-territories attack provision e.g. limiting car size to reach some structural column to prevent bomb attack
- Car Park patrol security
- Real Time PDA/PC housekeeping report/work with bar code system
- Concierge Building Management Service
- ATM banking service in building lobby

3.2 Bonus Features

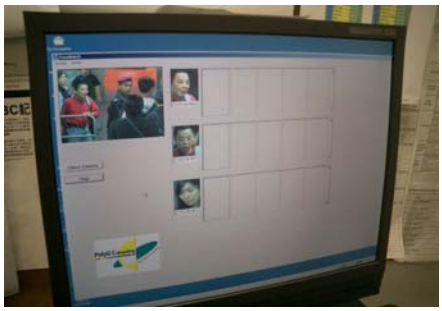
3.2.1 The complete Smart Card Access System

The most popular smart card in Hong Kong is called “Octopus”. In Hong Kong, every citizen has at least one Octopus store-valued card. This is a coin-less purse which is widely used in traveling, buying newspapers and breakfast on the journey into the office, and many more applications. The customized Octopus Card is used to identify the tenants and their employees of Two IFC when accessing the building and its facilities through a fully computerized access control system during normal and after office hours. The tenants and their employees are assigned a unique Personal Identification Number (PIN) on the Octopus card. The first assess control is at the concierge. The PIN is identified at the Octopus machine installed at the concierge desk for authorizing access to the lift lobby. The second access control is at the lift lobby. Especially during after office hours, the card is used by the tenants to operate lift to their own authorized office floors. For building visitors, registration is required at the concierge desk. A pass with bar code is issued to a visitor with designated assess in the building. It records the visitor’s name and identity with access in and out time in the computer.

Photo 2: Octopus Card Access

3.2.2 Face Recognition System for Security

A face recognition system is employed to check if there is any un-welcome person entering into the building. Contract-based workers are required to line up for recognition daily before they start to perform installation and repair works at the designated authorized floors. There is a camera installed at the line up location where all office decoration workers, delivery people, etc. will need a registration in order to enter the building via service lifts. In an un-noticeable way, their faces are automatically captured and be compared by the computer database if the are any black listed trouble makers.
The face recognition system is an intelligent video surveillance system that automatically detects and matches individual facial features for identification and authentication. The system extracts an image of the face from a video data stream and compares it to the pre-registered system database in real-time. The model-based coding of faces is operated through an original learning algorithm, which is a type of neural network model. It combines extraction of a region that resembles eye and facial features. Matching is possible when part of face is hidden due to a high-speed and high-precision face detection method focusing on uncovered parts. It compares the similarity of partial facial features with an adaptive regional blend matching system. The accuracy of result is up to 80% when approximately 200 pix is analyzed. This technology will definitely help in the terrorist and security control and should be widely employed in intelligent buildings.



Photos 3: Face Recognition System

3.2.3 Computerized Real Time Update Housekeeping System

A computerized real time reporting housekeeping system is developed by the management company. The system consists of a number of hand held PDAs to report of any tasks completion and working schedule. This wireless system enables an 'instant' reporting and communications among staffs and the central management system which allows them to operate in a highly efficient and secure manner. Barcodes set in the PDA which recognizes to offer control access and use of the facilities. This facilitates an intelligent housekeeping system.

Photo 4: Computerized Housekeeping System

3.2.4 Highly Efficient Security System

An integrated security programme is developed to safeguard tenants with the provision of anti-territories attack through proactive prevention methods and crisis response management.
Monthly car park tenants are designated at an area with barrier free optical turnstiles that can be installed at short notice. Suspected vehicles can be immediately blocked by restricted headroom. The visitor car park is located at designated car park perimeter zones. These parking zones are of low headroom and are well designed that any visitor car carrying explosives will not be able to damage any structural columns in case of any explosion event. In addition, bomb sniffer dogs with trained handlers patrol the loading bay and car park for detection of explosives during times of heightened security risk. To prevent thievery of cars at car park, there are patrol cars carrying out duty on a 24-hour basis.
Ten senior staffs form a crisis response team to deal with incidents ranging from fires and criminal acts through to catastrophic scenarios. They are equipped with pagers and supported by the building's internal public address system. This ensures the team can react at short notice in the event of a crisis or emergency. At each office floor, there are floor wardens who are nominated by tenant to liaise with the team during any emergency. In an event of an evacuation of the building, the team executes the evacuation plans through the internal paging system, guiding tenants efficiently to the assembly locations.
In addition, routine foot and vehicle patrols of the entire building are executed by both uniformed and plain clothes security personnel 24hours a day. X-ray equipment and bomb sniffer dogs are used to examine suspicious packages or mail at the post office of the building.

3.2.5 Concierge Building Management Service

Concierge management service is provided for tenants for hotel type of services. Services include air tickets reservations, flight confirmations, restaurant reservations, transportation arrangement, ferry ticket reservations, helicopter reservations, private jet arrangement, hotel reservations, visa assistance, mail service, courier service, sightseeing arrangement, gift and floral service, express printing, interpretation and translation service, mobile phone rental, language tutorial, residential properties search, short-term staff employment service, etc. The concierge service of Two IFC is extremely outstanding and receiving a lot of praises.

4. Conclusion

With the rapid construction together with the increasing demand for intelligent buildings in Asia and the world, the need for an independent and objective intelligent building assessment is immediate. The Intelligent Building Index (IBI) Manual Version 3.0 developed by the Asian Institute of Intelligent Buildings (AIIB) can be widely used as a practical tool for IB assessment. For details of the assessment method and calculation, it is recommended for readers to refer to the manual directly.

The experience of the assessment result on the Two International Finance Centre (Two IFC), the tallest building in Hong Kong, with the bonus features presented in this paper are solely for sharing of technical knowledge. There is much further information on technical and management practices for the building. Please refer to the AIIB web site www.aiib.net for details.

5. Acknowledgment

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