Implementation of certified intelligent building in Taiwan

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Abstract. Government of Taiwan since 2002 has been promoting certified and pre-certified intelligent buildings. It was introduced to meet occupant’s safety, comfort, convenience, and efficiency concerns with powerful automation and integrating systems in building. Energy saving, ease to maintained and management are the by-product of it. Based on total numbers of intelligent building permit issued and its total floor area, the certified and pre-certified intelligent building seems to be growing fast. However, the proportion between government owned and private sector projects are unbalanced. How to encourage private sector to participate and implement the certification of intelligent building is the aim of this study. To find out the possible factors that contributed the deferring of implementation on intelligent building from private sectors, experts in building construction industry include developers, architects, MEP integrators, real estate agents, and property managers have been invited to share the concerns. Delphi method was first used to develop the possible and consensus factors from the experts. Analytic hierarchy process was then used to rank the important key factors based on experts’ responses. The results could be utilized as basis for government agencies to formulate relevant policies and incentives on promoting certified and pre-certified intelligent building in private sectors.

1. Introduction
The rise of intelligent buildings is mainly due to the development of the telecom industry and the rapid advancement of various types of sensing technologies in automation technology. Countries such as United States of America and Japan have introduced these technologies into the construction industry, which has led to the development of intelligent buildings. Smart office buildings, smart shopping centers, smart parking lots, and smart houses are the common types of the intelligent building [1]. Intelligent buildings are the integration and management of automation systems in various fields [2, 3]. It primarily includes Communication Automation System (CAS), Building Automation System (BAS), Office Automation System (OAS), Fire Automation System (FAS) and Security Automation System (SAS) [4]. As these systems were developed individually and in different period of time with different technology available then, it is difficult to integrate these systems.
In 1980s, Taiwan began to introduce many related technologies of these automatic systems. Since then, through research and development as well as rigorous tests in market, manufactures gradually explored products that are suitable for the warm and humid environment in Taiwan. At the same time, it has gradually established an industrial chain of intelligent buildings.
In 2003, an executive order was set requiring all government construction projects costing more than 200 Million New Taiwanese Dollar to obtain certified and/or pre-certified Intelligent Building (IB)
status [5]. This regulation was officially launched in July 2003. Since then, the floor area of buildings that applied for the certified and pre-certified IB increased rapidly as shows in Figure 1 in red. The ratio of total floor area for the annual building permit issued versus certified and pre-certified IB projects has increased about 9.5% from 2015 to 2016 [6].

![Figure 1. Total floor area comparison between IB certified projects and annual building permit issued (Source: Wen, 2016).][5]

Table 1 indicates that the numbers of annual build permits issued to non-government own commercial offices (Type G) and residential housing (Type H2) projects are between 19257 to 24133. Despite the gradual increasing number of certified and pre-certified IB projects, only about 0.05% of total private sector owned Type G and Type H2 projects in the past 5 years have obtained IB certifications.

| Year | Number of Certified and Pre-certified IB Projects | Building Permits Issued Annually (Type G and Type H2 only) | Ratio of Certified and Pre-certified IB Projects to Annual Type G and Type H2 |
|------|-----------------------------------------------|-------------------------------------------------|--------------------------------------------------------------------------------|
| 2012 | 10                                            | 22365                                           | 0.03%                                                                         |
| 2013 | 20                                            | 23471                                           | 0.05%                                                                         |
| 2014 | 31                                            | 24119                                           | 0.06%                                                                         |
| 2015 | 53                                            | 24133                                           | 0.04%                                                                         |
| 2016 | 58                                            | 19257                                           | 0.05%                                                                         |

(Source: Wen, 2016)[5]

Figure 2 shows that certified and pre-certified IB projects are primarily government owned. Since most government-owned projects are big projects costing over 2 billion TWD and have larger floor areas, the total number of floor area of IB projects seems to have raised drastically. However with careful review, it is obvious to note that IB certified or pre-certified projects in private sector have actually decreased.
There are five levels of IB certification. They are certified, bronze, silver, gold and diamond. As shown in Figure 3, most of the IB projects achieved basic certified level. In particularly, there are at least 70% IB projects in 2016 acquiring the basic certified level and zero projects obtain gold and diamond certifications.

The above data reflects the willingness of developer to apply for the more stringent Intelligent Building Certificate. Thus, it is the objective of this research to find out possible factors from the building industry experts that can be used to improve or attract stakeholders to participate it.

2. Background and marketing of IB

2.1. IB certification

In 2003, Architecture and Building Research Institute (ABRI) of Minister of Interior in Taiwan published the Handbook of Definitions and Evaluation Criteria for Intelligent Building. This handbook sets up the national standardized evaluation criteria and certification procedures for IB projects. In 2011, the original handbook was revised with updated and advanced technology. The current version was published in 2016 with 8 indicators including unified wiring, information and
communication, system integration, facility management, safety and disaster prevention, health and comfort, convenience and friendliness, and energy efficiency and management.

Table 2 shows the five certified levels with the specific points requirement. There is a total of 200 points from the 8 indicators that can be obtained. Project with 50 points and below 90 points will meet the basic certified level. Project with 140 points and above will meet the diamond level [4, 7].

| Level       | Certified | Bronze | Silver | Gold       | Diamond     |
|-------------|-----------|--------|--------|------------|-------------|
| Score, point| Meet 8 indicators basic requirement | 50 to 90 | 90 to 120 | 120 to 139 | 140 and above |

There are two steps to acquire the IB certificate. Project with building permit and passed the review of IB evaluation criteria before construction completion is classified as pre-certified IB project. After completion, the pre-certified IB project with certificate of occupancy will become certified IB project and received a certificate with specific IB label.

2.2. Life cycle and innovation of product

To promote IB building, it is necessary to understand the development of IB building market. A study into the development of IB building market, the adoption of market life cycle and innovation of product concept is recommended. Consumer products have a rough progress of development, and their competitiveness in the market vary at different phases of the progress. Product developers will also adopt different strategies to meet the needs of consumers according to different phases [8].

Although buildings are long lasting goods and different from the general consumer products, their competitiveness and the need to be innovative are the same. According to Moore (2004), life cycle of market development can be divided into 9 phases [9]. Early market, the chasm, bowling alley and tornado are considered the technology adoption life cycle. Here, the product is introduced. It will be tested and sales will increase. Sense of novelty will be first boosted and disappeared a bit later. Once the product has been re-adjusted and improved at the early product improvement period, the sense of novelty from consumers will increase and sales will increase significantly [10]. It is then followed by the product’s mass-production period. Sales are stable. Once the technology is outdated, sales will decrease and eventually reached the end of life for the product.

2.3. Buyer utility map

Kim & Mauborgne (2000) mentioned that companies mostly understand the challenges of engaging in innovation [11]. New products must be able to offer special effects or services to consumers at attractive prices, and bring a considerable profit to enterprises. Many innovators pursue technological breakthroughs and create new products. However, they often overlook the needs of consumers or the interests of enterprises. In order to avoid such a situation, buyer utility map is proposed for decision making. Essentially, it is a 6-factors matrix with the buyers’ experience cycle of purchasing a product versus the utility level. Buyer’ experience cycle from purchasing products to abandoning the product is divided into six stages: purchase, delivery (house) goods, use, supplement (expansion) charge, maintenance, and processing.

The utility level of product is also divided into 6 stages: customer productivity, simplicity, convenience, risk, fun and image, and environmental friendliness. Based on market-shaping blue ocean strategy, as a rule of thumb, only provide one utility level factor to one dedicated product cycle to attract customers. For example, during the purchase stage of an IB certified house; convenience can be the product image to attract customer. Likewise, in use stage, simplicity is the image to attract
customer. With this buyer utility map in mind, it is easy to see the differences between the new product and exiting product. Marketing strategies can be formulated then.

3. Delphi method and Analytic Hierarchy Process
This study used Delphi method and Analytic Hierarchy Process (AHP). It is so called DHP by Khorranshadhgol and Moustakis in 1988 [12]. For Delphi method, a group of experts will be asked to participate in questionnaires anonymously for couple rounds and until the results are consistent [13, 14, 15].

These experts should be selected with consideration relative to the research topics and have experience in the field. It is also the intent to conduct questionnaire anonymously so that the complicated and divergence factors can be derived to a final list without confrontation between the groups of experts [16]. (Linstone & Murray, 2002) Feedback control is often used, so that experts have opportunities to re-think the outcome based on trends of other participants. The results will then be used in AHP for the ranking analysis. AHP is introduced by Saaty in 1971. As any complicated issue, there must be an underlying hierarchy order of factors [17, 18]. Pairwise comparison method with 9 scale is used to reveal the importance of one factor to the other and as shows in Table 3. As score 1 means A and B are equal important. Score ± 3 means a moderate importance of a factor than the other. Score 5 means one factor is basically believed and prefer as an important factor than the other. Scores 7 and 9 indicates the strong and absolute preference toward one factor. Intermediated levels are 2, 4, 6 and 8.

### Table 3. AHP Fundamental Scale (Source: Saaty, 1990)[19]

| Factor A | Equal importance | Moderate importance of one over another | Strong or essential importance | Very strong or demonstrated importance | Extreme importance | Factor B |
|----------|------------------|----------------------------------------|-------------------------------|---------------------------------------|-------------------|----------|
| A        | 1                | 3                                      | 5                             | 7                                     | 9                 | B        |

Matrix with the same order of factors in horizontal rows and vertical columns could be used as the template for the questionnaire. Participant is asking to look at one factor from the horizontal row and compare with rest of the factors from the vertical columns. Scale from 1 to 9 can be entered as stated in Table 1 for each pairwise comparison. The diagonal cell eventually will become 1 since it compares the same factor. All data will be normalized, so that the overall comparison scores between one factor to the rest of the factors equal one. Consistency ratio calculation will be performed. A list of factors with mean value and ranking will be derived.

4. Data analyses and results

4.1. Level of importance and agreeing on factors

Nine architecture and construction industry experts participated in three rounds of questionnaires using Delphi method. Table 4 lists the expertise and ratio for the nine experts. The average working experience is over 15 years.

### Table 4. Expertise and ratio of the participants

| Expertise of Participants (Including Architect) | Developer | MEP Integrator | Real Estate Agent | Property Manager |
|-----------------------------------------------|-----------|----------------|-------------------|-------------------|
| Number                                        | 3         | 2              | 2                 | 2                 |
| Ratio                                         | 33.33%    | 22.22%         | 22.22%            | 22.22%            |
Eighteen factors such as schedule required, lack of common standard, extra maintenance work, web security, extra costs, high maintenance costs, unknown total costs, low profit rate, products outdated, lack of incentives, perception differences, lack of capable firms, non-perceived extra value, extra installation costs, not attractive enough, budget limitation, and extra transferring costs were derived from first round’s responses.

The results were used as the basis for second round questionnaires. Likert scale was used to evaluate the importance of the factors for the second rounds. To further differentiate the level of agreement for responses from second and third rounds, quartile deviation (Q) were used. Table 5 shows the quartile deviation value to the corresponding level of agreement on a factor. According to Faherty (1979) and Holden et al (1993), when Q is equal and or less than 0.6, it indicates the participants agree highly on a factor[14, 20]. Likewise, when Q is greater 1.0, it means there is a low level of agreement on a factor. Greater than 0.6 and less than or equal to 1.0 indicates the participants achieve moderate agreement on a factor.

| Table 5. Quartile deviation value to the corresponding level of agreement on a factor |
|---------------------------------|--------|--------|--------|
| Quartile Deviation (Q) | Q ≤ 0.6 | 0.6 < Q ≤ 1.0 | Q > 1.0 |
| Level of Agreement | High | Medium | Low |

Table 6 shows the eighteen factors from second and third rounds with mean value of importance level and the Q for the agreeing level. It is to note that a “-“ is used in third round data as a factor gets Q ≤ 0.6 in second rounds. It simply indicates that the importance level of this factor has been agreed with by participants in the second round. In addition, to shorten the list of the factors, factors with mean value equal to 4 and above as well as with Q ≤ 0.6 were selected for the analytic hierarchy process analysis. Ten factors derived. These are lack of common standard, extra maintenance work, extra costs, low profit rate, lack of incentives, perception differences, lack of capable firms, extra installation costs, not attractive enough, and budget limitation.

| Table 6. Levels of importance and agreeing of the eighteen factors from round 2 and 3 |
|---------------------------------|--------|--------|
| Factors | Round | Mean | Q |
| Schedule required | 2 | 3.11 | 0.5 |
| | 3 | - | - |
| Lack of common standard | 2 | 3.67 | 1 |
| | 3 | 4.11 | 0.5 |
| Extra maintenance work | 2 | 3.56 | 0.5 |
| | 3 | 4.00 | 0 |
| Web security | 2 | 2.78 | 0.5 |
| | 3 | - | - |
| Extra costs | 2 | 3.67 | 1 |
| | 3 | 4.11 | 0.5 |
| High maintenance costs | 2 | 3.67 | 0.5 |
| | 3 | 3.56 | 0.5 |
| Unknown total costs | 2 | 3.11 | 1 |
| | 3 | 2.89 | 0.5 |
| Low profit rate | 2 | 3.78 | 1 |
| | 3 | 4.11 | 0.5 |
| Products outdated | 2 | 3.56 | 0.5 |
| | 3 | 3.56 | 0.5 |
| Lack of incentives | 2 | 4.44 | 0.5 |
| | 3 | - | - |
| Perception differences | 2 | 3.89 | 0.5 |
4.2. Results of AHP analysis

Prior to performing AHP analysis on the ten factors, three pre-tests with irrelevant questions to this study were conducted to see if the consistency ratio (CR ≤ 0.1) can be achieved by the participants. First pre-test with three factors were used for evaluation. Second and third pre-tests with five factors were used. According to Saaty & Tran (2007), consistency ratio is the measure of consistency of evaluations for a set of data. It is the ratio of consistency index (CI) to the random index (RI) [14, 20]. Consistency index is calculated from the pairwise comparison matrix for the minimum changes of numbers in a dataset and divided by the actual numbers’ changes. Random index is shown in Table 7.

Table 7. Random index (Source: Saaty et al, 2007)

| Order | 1    | 2    | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    |
|-------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|
| R.I.  | 0.00 | 0.00 | 0.52  | 0.89  | 1.11  | 1.25  | 1.35  | 1.40  | 1.45  | 1.49  |
| First order differences | 0.00 | 0.52 | 0.37 | 0.22 | 0.14 | 0.10 | 0.05 | 0.05 | 0.04 |       |

Table 8 summaries the pre-tests’ results with the consistency ratio values. It indicated that participant E and G were having inconsistency results on pre-test 1. After communicating with these two participants for the paradox answers, the modified pre-test 1 result showed the value of CR ≤ 0.1.

Table 8. Consistency ratio for the three pre-tests (Source: Saaty et al, 2007)

| Participant | Pre-test #1 with 3 factors | Modified Pre-test #1 with 3 factors | Pre-test #2 with 5 factors | Pre-test #3 with 5 factors |
|-------------|---------------------------|-------------------------------------|---------------------------|---------------------------|
| A           | 0.00                      | 0.03                                | 0.06                      |                           |
| B           | 0.00                      | 0.04                                | 0.05                      |                           |
| C           | 0.12                      | 0.06                                | 0.07                      | 0.09                      |
| D           | 0.01                      | 0.06                                | 0.06                      | 0.05                      |
| E           | 0.06                      | 0.09                                |                           | 0.07                      |
| F           | 0.01                      | 0.06                                |                           | 0.07                      |
| G           | 0.12                      | 0.00                                | 0.07                      | 0.05                      |
| H           | 0.01                      | 0.05                                | 0.06                      |                           |
| I           | 0.03                      | 0.08                                | 0.07                      |                           |
Since all of participants achieved the agreements on the pre-tests, the ten IB factors were then used as the AHP question basis during interview with experts. As shows in Table 9, consistency ratio has been calculated for this AHP interview results and with CR ≤ 0.1.

Table 9. Consistency ratio for AHP interview results

| Expert | A   | B   | C   | D   | E   | F   | G   | H   | I   |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Consistency Ratio | 0.078 | 0.085 | 0.085 | 0.091 | 0.091 | 0.063 | 0.070 | 0.075 | 0.084 |

The weighting scores of each expert for the ten factors are showed in Table 10. Higher weighting score indicates the stronger the factor. For example, expert A considered lack of incentives is more important than the other factors for implementing IB certification in Taiwan. It is also agreed by other experts, expect expert I.

Table 10. AHP weighting scores of each expert

| Factors                             | A       | B       | C       | D       | E       | F       | G       | H       | I       |
|-------------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| A: Lack of common standard          | 0.095   | 0.028   | 0.032   | 0.039   | 0.026   | 0.062   | 0.019   | 0.026   | 0.016   |
| B: Extra maintenance work           | 0.035   | 0.060   | 0.057   | 0.036   | 0.049   | 0.029   | 0.081   | 0.064   | 0.030   |
| C: Extra costs                      | 0.050   | 0.133   | 0.018   | 0.068   | 0.018   | 0.154   | 0.046   | 0.123   | 0.168   |
| D: Low profit rate                  | 0.036   | 0.229   | 0.163   | 0.019   | 0.131   | 0.129   | 0.118   | 0.063   | 0.083   |
| E: Lack of incentives               | 0.314   | 0.020   | 0.317   | 0.289   | 0.289   | 0.288   | 0.255   | 0.310   | 0.032   |
| F: Perception differences           | 0.104   | 0.256   | 0.068   | 0.018   | 0.107   | 0.072   | 0.045   | 0.142   | 0.071   |
| G: Lack of capable firms            | 0.042   | 0.094   | 0.085   | 0.093   | 0.087   | 0.023   | 0.033   | 0.095   | 0.114   |
| H: Extra installation costs         | 0.031   | 0.037   | 0.042   | 0.141   | 0.047   | 0.020   | 0.087   | 0.062   | 0.194   |
| I: Not attractive enough            | 0.105   | 0.045   | 0.059   | 0.165   | 0.112   | 0.143   | 0.162   | 0.085   | 0.068   |
| J: Budget limitation                | 0.190   | 0.099   | 0.159   | 0.132   | 0.134   | 0.080   | 0.154   | 0.031   | 0.224   |

The mean and ranking of the ten IB factors for overall and groups of experts are showed in Table 11. It is obvious to find that lack of incentives, budget limitation and low profit rate are the top three factors that is hindering the implementation of IB certification in Taiwan. However, for developers, architects and property managers, the factor “not attractive enough” weighted a bit more than the factor, “low profit rate”. For MEP integrator, “perception differences” ranked as the most important factor. “Extra costs” is weighted as the primary factor for the real estate agent group.

Table 11. Mean and ranking of ten IB factors for the overall and the groups of expert

| Factors                             | Overall Mean | Developer (Including Architect) Mean | MEP Integrator Mean | Real Estate Agent Mean | Property Manager Mean |
|-------------------------------------|--------------|-------------------------------------|--------------------|-----------------------|-----------------------|
| E: Lack of incentives               | 0.235        | 0.299                               | 0.167              | 0.160                 | 0.283                 |
| J: Budget limitation                | 0.134        | 0.142                               | 0.144              | 0.152                 | 0.092                 |
| D: Low profit rate                  | 0.105        | 0.104                               | 0.133              | 0.106                 | 0.090                 |
| I: Not attractive enough            | 0.105        | 0.112                               | 0.075              | 0.106                 | 0.123                 |
| F: Perception differences           | 0.098        | 0.064                               | 0.180              | 0.072                 | 0.094                 |
| C: Extra costs                      | 0.086        | 0.034                               | 0.091              | 0.161                 | 0.084                 |
| G: Lack of capable firms            | 0.074        | 0.089                               | 0.068              | 0.069                 | 0.064                 |
| H: Extra installation costs         | 0.073        | 0.077                               | 0.034              | 0.107                 | 0.074                 |
| B: Extra maintenance work           | 0.049        | 0.047                               | 0.048              | 0.030                 | 0.073                 |
work A:Lack of common standard

|      |   |   |   |   |   |   |   |
|------|---|---|---|---|---|---|---|
| 0.038| 10| 0.033| 10| 0.061| 8| 0.039| 9|
| 0.023| 10|

5. Conclusion

Through this study, the primary factors constraining the implementation of IB certification in Taiwan for private sectors have been concluded. Lack of government incentives ranked the most important factor. This could plausibly explain the concern over budget limitation and low profit margin from the developer’s perspective.

In addition, the high costs of housing in Taiwan as well as unfamiliarity with IB certification and its advantages could also contribute to this standstill state for purchasing.

Yet, from building industry market analysis, it is true that IB and high-tech consumed product have similar phases in the technology adaptation cycle. During the cycle, the order of four phases such as early market, the chasm, bowling alley and tornado is chaotic. The updated technology along with the new business model and product could exist.

Profitable market during the cycle could not easily be hold on by the developer, as it takes longer to produce a building than a product. Thus, it requires extra effort for building industry companies to consider the necessary support for consumer to own the IB through its entire life cycle. One developer in Taiwan has successfully done the work by providing free operation and management services for the first two ye

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