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Tutorial for Matrix Tool for Assessing the Performance of Intelligent Buildings

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A method that allows for a consistent assessment of the performance of intelligent buildings is required in order to identify the requirements of building developers and operators and hence facilitate the acceleration of the market penetration of SMART building technologies. A matrix tool, "Matool", has been developed in order to fill the gap by presenting a practical and feasible manner for assessing the intelligence of buildings.
The matrix tool takes into account the following three elements (criteria):

- The built environment should provide for the safety, health, and productivity of the occupants by meeting the requirements for thermal, visual and acoustic comfort and indoor air quality.
- The building should have the potential to serve future generations through sustainability, or adaptability over the life cycle of the building, and the safeguarding of environment resources.
- The building can be constructed and operated within some financial constraints whilst retaining market value.

The Matool has been developed for assessing the intelligence of buildings during design, procurement and operation. The objective was to develop a tool that would assist in the identification of the weak points of the building project remit, design or operation and indicate where intelligence may be improved.

Background

The basis of the Matrix Tool is the definition of the Intelligent Building as a building that:

- Provides a productive and cost-effective built environment through optimization of its four basic components - structure, systems, services and management - and the interrelationships between them (focusing on the benefit of the owners, i.e. creating the desired indoor environment)
- Maximizes the quality of the indoor environment (focusing on the benefit of the occupants, i.e. impact of meeting desired indoor environmental conditions on occupants)
- Allows effective management of resource with minimum life cycle costs (focusing on the benefit of the environment, i.e. through minimum environmental impact whilst maximising economic impact)

Over the years relevant technologies for use in designing, constructing and operating intelligent buildings have significantly progressed and are still being rapidly developed.

Plenty of intelligent buildings have been built. However, how intelligent these buildings actually are compared with conventional buildings is often a question. Due to the lack of a commonly accepted method and pertinent supporting data, assessing the overall performance of intelligent buildings can't be carried out on a solid ground. It is difficult, if not impossible, to carry out like-to-like comparison between different buildings in term of intelligence. As a result, the industry still goes without adequate knowledge about the best practice of intelligent building.
This matrix tool should be used by facility managers and construction professionals to allow the assessment of the following performance indicators of the building:

- Built Environment
- Responsiveness
- Functionality
- Economic Issues
- Suitability

Scope of assessment

Five performance indicators are specified and used:

- Built Environment which consists of the following sub-performance indicators:
  - Comfort and productivity: to what extent does the building meet the comfort criteria of the occupants?
  - Individual control of local environment: do occupants have the ability to adjust the set-point of their local terminal devices, e.g. fan-coil unit or blinds?
  - Health and safety: is a safe and healthy environment created?
  - Energy and environmental policy: is there an adopted organisational policy on the operation of the built environment and the associated environmental impacts?
  - Integration with the surrounding ecological systems: how have decision been made during the design phase regarding to micro-climatic design, building integrated renewable energy sources and rainwater/wastewater utilisation.
- Responsiveness
  - Awareness: how well do the occupants understand their relationship with the building?
  - Automatic response to changes in the surroundings: are there any measures or systems that allow the building to appropriately responds to the changes in the surroundings, utility supply, services systems and usage of the buildings?
  - Performance under emergency situations: what level of emergencies can be handled within and around the building?
  - Decision-making: are the building operators free to make decisions in response to changes in requirements?
  - Flexible usage: is it flexible to alter the partitions, layouts and service systems for different usage?
- Functionality

  - Reporting system: how well is the information associated with the efficient management and operation of the building is communicated to the relevant parties?
  - Building Management System (BMS): is there a BMS installed and to what extent is it being utilised?
  - Maintenance: how is the building, including architectural features, BMS (if any), and services systems, maintained?
  - Facility Management (FM): is there a facilities manager or management team and how technically competent are they?
  - Easy-to-use through design: how the issues related to the ease of use is considered in the design phase?
- Economic issues
  - Investment: are the potential investments in advanced or intelligent building technologies evaluated by the relevant decision makers?
  - Energy supply: how easy (or difficulty) is it to change the supply of energy?
  - Resources (water, waste treatment, etc): how are energy auditing, monitoring of water usage, and waste treatment carried out?
  - Costs: how are the operating costs associated with energy and other utilities paid by tenants?
  - Budget: what procedure is employed to determine the ratio of the initial construction cost to the life cycle cost?
- Suitability
  - Special use: does the building provide features to satisfy special needs of some individuals such as the disabled or elderly?
  - IT connectivity: does the building have access to specialist services providers through an IT network?
  - Location: is the building located such that the activities within the building have easy access to the relevant sources?
  - Organisation: is there an appropriate communication between different divisions of the organisation that allows effective dissemination of information associated with efficient operation of the building?
  - Internal flow and operational planning: what process or methods are employed in the design phase to make decisions associated with the location of interacting divisions in the building and the movements of staff and information?

These Intelligent Building Performance Indicators performance indicators are influenced by a number of factors, or Fields of Impact. This Matrix Tool only considers the five factors, as follows:

- People
  - Do they feel comfort and are they productive in the building?
  - How well do they understand their relationship with the building?
  - Do they have a role in the energy management?
  - Investment decision-makers: do they understand the benefit of intelligent building technologies and are they willing to investigate the feasibility of relevant investment?
  - People with special needs (such as the disabled and elderly): can the building satisfy their special needs?
- Building systems

- Does the system provide facilities for individuals to change the set-point of local devices according to their desire?
- Are the building and its systems automatically responsive to the surroundings?
- Is the building controlled and managed by a Building Management System (BMS)?
- Is it technically feasible to change the suppliers of utilities when considered beneficial?
- Does the building have good access to the internet?

- Critical
  - What measures are there to ensure the safety and health of people staying in and around the building?
  - Which of the facilities are equipped to handle emergencies?
  - What is the status of the maintenance of the building and service systems?
  - What is the status of energy auditing, waste treatment and management and the use of renewable energy sources?
  - Is the building in an appropriate location for it's use?
- Process
  - Is there an adopted energy and environmental policy within the organisation?
  - What is the independence of operators in dealing with any necessary change?
  - Is there a facilities manager or management team?
  - What are the facilities for individual tenants to control and meter their utilities?
  - How is the organisation structured?
- Design
  - What were the design considerations and decisions on the integration of the building and its systems with the surroundings?
  - What were the design considerations and decisions on possible change of partitions, layout and services systems required by the change of usage?
  - How easy is it to use, operate and maintain the building systems?
  - How is the cost of the building related to its' lifecycle?
  - Are interacting divisions easily accessible?

Each of the five Intelligent Building Performance Indicators is influenced by all five Fields of Impact. Their interactions are considered in the Matrix Tool. A Checklist, designed in accordance with the above description, has been developed for walk-through survey of intelligent buildings (see ***Appendix A***). This check lists assists in the evaluation of the intelligence of the building based on a total of 25 separate aspects of the building.

Each of the performance indicators has a value ranging from 0 to 5, with 5 indicating the best and 0 indicating the worst. Once these individual performance indicators are assessed against the relevant building features, the overall performance is computed as below:

$$IQ = g_B P_B + g_R P_R + g_F P_F + g_E P_E + g_S P_S$$

where:

P_B P_R P_F P_E P_S are the value of individual performance indicators: Built Environment, Responsiveness, Functionality, Economic and Suitability respectively

g_B g_R g_F g_E g_S are respectively the weighting factors for individual performance indicators .

And:

$$g_B + g_R + g_F + g_E + g_S = 5$$

The value of IQ specifies the "intelligence" of a building under the "Matool". The maximum value of IQ is 125. The rating of the intelligent building is accordingly specified as follows:

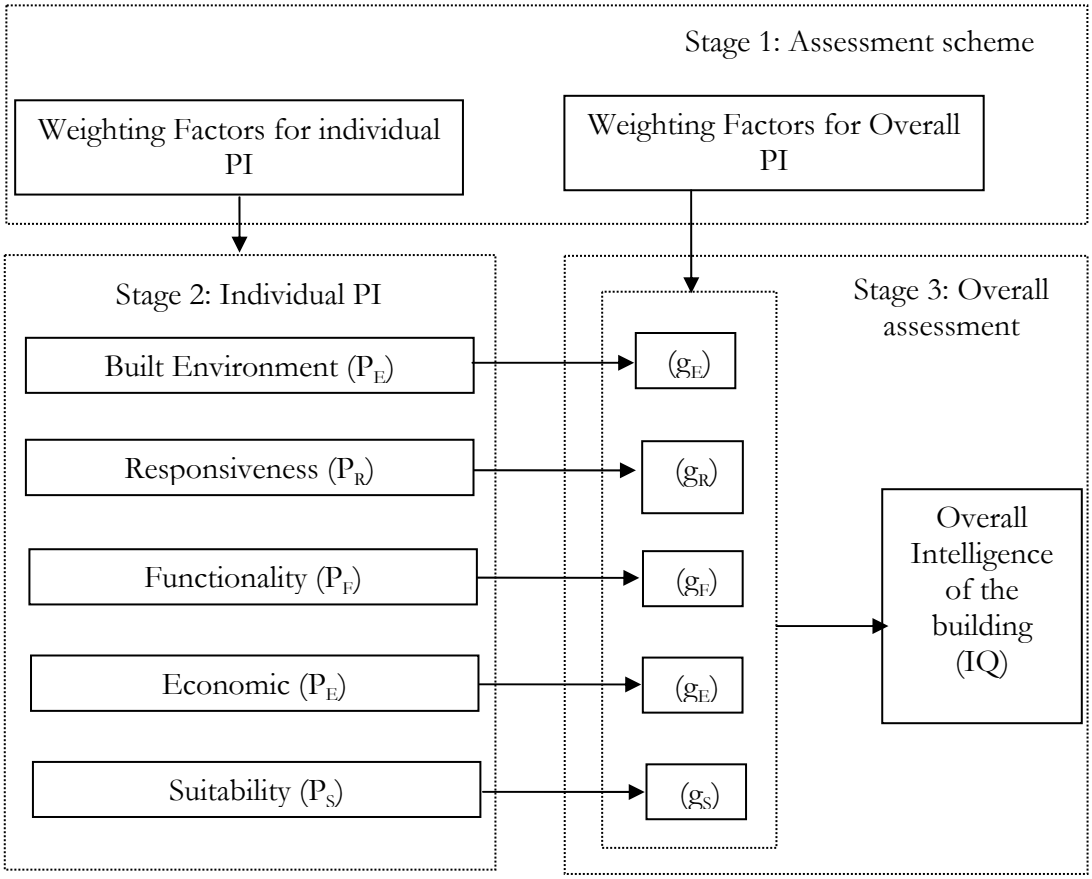
- Bad: <50
- Good: 50 ~80
- Very Good: 80 ~100
- Excellent: 100~125

The building is assessed using the developed questionnaire. A PI may be affected by all or some of building features described below. Building features and their interaction with each other, with the user and with the environment determine the performance of a building. The building features are identified in "Matool" as below:

- Site, locations
  - The building location
  - Utility services
  - Accessibility
  - Facilities nearby
  - Convenience of site and location for building users, visitors and business clients.
- Building envelope, core and space layout
  - The building form
  - Internal space layout, depth, floor to floor height, grid, form, internal partition
  - Maximum distance to fire escape
  - Occupancy density
  - Atria, etc.
- Amenities
  - External access
  - Circulation
  - Toilets and common rooms, public areas,
  - Servicing facilities
- Structure
  - Safety and protection against earthquake, subsidence, flooding
  - Future extension
  - Span, load
  - Embedded monitoring
- Materials
  - Energy performance
  - Internal environment quality (IAQ)
  - Sustainability (embedded energy, recycling, waste treatment)
- Façade and cladding

  - Glazing
  - Cladding
  - Shading
  - Natural ventilation and lighting features
  - Use of solar energy (heat collect or PV)
- Environmental system
  - HVAC
  - Passive and active solar system
  - Natural ventilation
- Mechanical system
  - Vertical transportation
  - Plumbing, water storage, cleaning system, waste disposal
  - Recycling system
- Electrical system
  - Power supply
  - Lighting
  - Lightning protection
- IT and communication system
  - Telephone, fax, computing
  - LAN, WAN
  - TV & Radio
- Fire safety system
  - Fire prediction/detection system
  - Fire alarm system
  - Fire protection system
  - Fire fighting system
- Building management system
  - Security system
  - HVAC control
  - Lighting control
  - Vertical transportation control

All these building features directly influence each individual performance indicator and the overall performance, or the "Intelligence" under "Matool", of a building.
This is illustrated in the following figure.



Quality Control

"Matool" is to be carried out by certificated engineers. The certificate will be issued to the engineers who successfully finished necessary training course and passed the examinations designated to test examinee's knowledge about the "Matool" scheme.
"Matool" scheme will be regularly reviewed to ensure that the scheme is most updated with the current practice in different regions. Any modification made to the scheme during the review will be communicated to all certificated engineers so that the most updated assessing method is employed.
The following organisations can provide training for using Matool:
BRE (UK)
All the other partners in the project

References

[1] R. Baldwin, A. Yates, N. Howard, and S. Rao (1998), BREEAM 98 for offices, An environmental assessment method for office buildings, BR 350, ISBN 1 86081 2384