INTELLIGENT BUILDINGS: Definitions, Need and Models

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OUTLINE

A. Introduction- why are buildings needed
B. What is “intelligence”?
C. Need and drivers for IB
D. Models of IB
E. Metrics of productivity
F. Future trends

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A. Intro- Hierarchy of Needs in Buildings

Maslow' Triangle

- Safety (security from elements and animals/people)
- Physiological comfort (heating, cooling, light, water,...)
- Social (telecom, office automation,...)
- Personal (dynamic tools to maximize occupant productivity and satisfaction)

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A. Basically

- Sound business investment
- Provide for occupant comfort and safety
- Socially responsive

... in this order

Intelligent...Automated...Green...Sustainable...?

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A. Issues: Business Perspective

- Least cost to build, maintain, operate
- Maximum flexibility in use

Difficulty is that

- Most buildings are unique
- Different building types and size
- Different building systems
- Owner , tenant and other stakeholders

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A. Introduction

Building Operation/Services

1. Facilities management (bldg maintenance, power, HVAC&R systems, lights, grounds,...)
2. Inspections, renovations, retrofits, O&M,...
3. Dynamic operation: Automated FDD, active load control, supervisory control
4. Management of other building services (fire,...)
5. Telecom and allied services
6. Billing services
7. Space/property management

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A. Introduction

Building Systems:

1. Architectural
2. Geotechnical/structural
3. Envelope/shell
4. HVAC&R systems and control
5. Other building services (power, lights, equip., fire safety, acoustical, plumbing, sanitary,...)
6. Telecom
7. Security/surveillance/ building access

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B. What is "Intelligence" ?

Dictionary Definitions

- Knowledge:
  awareness, learning, understanding or skill gained by education or experience
- Smart/intelligence:
  ability to deal with new situations and solve problems
- Wisdom:
  ability to see behind surface of things

degree of intelligence interlinked with knowledge

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B. Knowledge Acquisition Methods

- Intuition (hard wired)
- Unconscious (child)
- Conscious (books, school, self-study…)

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B. What Is "Intelligence" ?

Traits from layperson perspective:

- Ability to think
- take logical decisions
- learn from past experiences
- handle new situations
- adapt to new situations
- take decisions based on incomplete data

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B. Artificial Intelligence (AI)?

- Means different things to different people
- Ambiguous definition
- Humans revel in the uniqueness and superiority of the human mind
- AI perceived as a science dealing with the creation of intelligence
- Consequently viewed as a THREAT to humans, triggers a deep-seated survival instinct

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B. AI and Human Intelligence

- Artificial- comes from engineering
- Intelligence- comes from psychology
- AI is an oxymoron (like jumbo shrimp)

AI or computer architectures can be basically different from human mind

Ex: airplanes/helicopters do not have the same skeletons as birds, yet they fly

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B. Objective of AI

Though philosophical issues cannot be avoided entirely, better to separate philosophy from technology

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B. Artificial Intelligence (AI) deals with:

Computer Science definition

- new ways of representing tacit knowledge
- new ways of organizing knowledge
- efficient techniques for manipulating and searching this knowledge for solutions
- learning from past experiences and adapt
- adapting/responding to new situations not encountered previously
- process inferences rather than manipulating of numeric info only- similar to human thinking

AI encompasses both knowledge and intelligence

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B. Types of "Intelligence" ?

Levels of Intelligence

- Systems that exhibit very specialized and narrow capabilities (autistic person)
- Systems that exhibit less specialized but wider capabilities

Should both these aspects be included in our definition?

Enhanced Capability

- Performing more efficiently things currently being done
- Performing new things which could not be done before

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B. What Is "Intelligence" ?

Working definition:

Intelligent Infrastructure Systems are those that can:

- sense
- integrate and communicate
- reason, decide and take action (optimize performance)
- learn (adapt operation to needs of occupants and operating conditions)

while meeting the intended objectives

This does not include "intelligent design" !

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B. Types of "Intelligence" ?

- Passive Intelligence:

Intelligent in conception (innovative design)

- Active or Dynamic Intelligence:

Intelligent in operation

Difficult to characterize intelligence:

For example: limitation of SAT exams

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C. Need and Drivers for IB

- Business proposition
  - increase occupant productivity
  - flexibility in space usage….
- Keeps occupants safer and comfortable
- Current push for "sustainable"
  - declining energy resources
  - adverse environmental impact….

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C. Need and Drivers for IB

High building energy use

1. Fraction of nation's primary energy use: 36%
   or close to $200 billion/year
2. Fraction of total electric use: 66%
3. Over 80% of commercial space > 10 years old
   2% undergoes major retrofit per year
4. Ever-growing electric demand and low capacity increase
5. OTA(1998): 15-25% of energy use can be saved by current cost-effective technology

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C. Need and Drivers for IB

- Current building design is generally poor and not well adapted to environment

  - downtown commercial buildings
  - building codes

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C. Need and Drivers for IB

Poorly maintained buildings

PECI (1998): Study on 60 commercial buildings

- More than half had control problems
- 40% had problems with HVAC&R equipment
- 33% had sensor problems

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C. Need and Drivers for IB

Others

1. Phases of Buildings involving design, construction, commissioning, operation and maintenance can be better integrated
2. Decreasing number of skilled people with domain-specific knowledge
3. Increasing cost of skilled people
4. Ageing infrastructure

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C. Need and Drivers for IB

IB are more expensive to build, they will be adopted if:

- owner: increase ROI (retaining tenants by maintaining responsive environment, minimizing operating costs)
- tenant: increase profitability of business
- employee: increase productivity, safety, comfort
- policy makers: more “sustainable” by way of decreasing adverse environmental impact

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D. Models of Intelligent Buildings

Several definitions:

- Asia (Singapore, China, Japan)
- UK- European IB Group
  emphasis on user’s requirements
- USA – IB Institute (IBI)
  emphasis on availability of technologies
  easier to quantify

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D. Models of IB

IB originated in early 1980 in the US where it denoted buildings with sophisticated telecom, bldg management and data networking services that provided shared tenant services to occupants

1980- collection of innovative technologies
1990 – above + able to respond to organizational changes over time
1992- Tools that provide a responsive, effective and supportive environment within which the organization can achieve its business objectives

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D. Models of IB- USA

One which provides a productive and cost-effective environment through optimization of its four basic elements

- structure
- systems
- services
- management

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D. Model of IB- Asia

So and Chan (1999):

> An IB is designed and constructed on an appropriate selection of quality environment modules to meet the user's requirements by mapping to the appropriate building facilities to achieve a long-termed building value

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D. Model of IB- UK

Boyd (1994):

> One that creates an environment which maximizes the effectiveness of the building's occupants while enabling efficient management of resources with minimum life-cycle costs of hardware and facilities

My preferred "academic" definition

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E. Metrics of "Intelligence" ?

How to measure and evaluate parameters, qualities and capabilities of intelligent systems compared to those demonstrated by living creatures?

No fixed set of attributes

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E. Rating of IB

How to measure and evaluate parameters, qualities and capabilities of IB so as to rate it?

Very difficult*:*

so used check-list approach

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E. Building Rating Metrics

Business Objective – Building is a tool which enhances organizational output
- Business enterprise: increase profits
  (type of business, occupant comfort, productivity,..)
- Building owner: higher ROI
  (tenant retention, higher rents, lowest facility cost,..)

Societal Objective: Minimizes adverse env impact from life cycle viewpoint

Can we quantify gains by investing in intelligence?
What to measure, when, what to compare against?

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Building Rating Method (BRM) Questionnaire

Section A: Building site/location
- A1 Locale
- A2 Site communications infrastructure
- A3 Provision of local amenities
- A4 Access to site by public and private transport
- A5 Access to carparks
- A6 Site and building security
- A7 Aspect

Section B: Building shell issues
- B1 Thermal shell strategy
- B2 Structural grid
- B3 Planning and partition grids
- B4 Floor size and configuration
- B5 Floor shape
- B6 Space efficiency
- B7 Floor depth and sectional height
- B8 Imposed floor loadings
- B9 Provision of high load areas
- B10 Communications infrastructure
- B11 Staff and visitor access
- B12 Goods access
- B13 Exterior/interior maintainability
- B14 Atrium provision

Section C: Building skin issues
- C1 Services strategy
- C2 Solar control strategy
- C3 Natural ventilation

Section D: Organizational and work process issues
- D1 Organizational complexity
- D2 Amount of relocation
- D3 Routineness of work
- D4 Individual or work group
- D5 Work location
- D6 Need for privacy
- D7 Use of information technology
- D8 Use of wide area communications
- D9 Control of the work environment
- D10 Concern about security
- D11 Access to workplace out of hours

Section E: Building services and technology
- E1 HVAC zoning and control
- E2 Small power supply
- E3 Back-up power provision
- E4 Cable distribution system
- E5 Communication systems
- E6 Lighting sytems
- E7 Building automation systems
- E8 Space management systems
- E9 Business systems
- E10 Access control and security
- E11 Furniture systems
- E12 Quality of finishes/installation and maintenance (fit-out)

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LEED EVALUATION

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LEED Defined

- Leadership in Energy and Environmental Design (LEED)
  - LEED-NC Version 2.1
  - LEED-NC Version 2.2
  - Scoring System
    - 26-32 Points – Certified
    - 33-38 Points – Silver
    - 39-51 Points – Gold
    - 52-69 Points - Platinum

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LEED Evaluation

- LEED-NC Version 2.1
- Six Categories
  - Sustainable Site
  - Water Efficiency
  - Energy & Atmosphere
  - Materials & Resources
  - Indoor Environmental Quality
  - Innovation & Design Process

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LEED Evaluation

- Sustainable Sites
  - Persuade developers/owners to be more conscientious when selecting a site
    - Reduce environmental impact & to habitat
    - Rehabilitate damaged sites
    - Reduce pollution & land development impacts from automobile use

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LEED Evaluation

- Water Efficiency
  - Reduce water usage
    - Water use reduction within building
    - Reduction of water in landscaping
    - Innovative wastewater technologies
- Energy & Atmosphere
  - Reduce Energy Consumption
    - Energy efficiency
  - Environmental
    - Ozone protection
    - Renewable energy
    - Green Power

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LEED Evaluation

- Materials & Resources
  - Reduce Waste
    - Building & materials reuse
    - Recycled materials
    - Regional material
  - Environment
    - Certified wood
    - Rapidly renewable materials

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LEED Evaluation

- Indoor Environmental Quality
  - Reduce potential hazard to occupants
    - Low-Emitting materials
    - Chemical & pollutant source control
    - Indoor Air Quality Management Control
  - Comfort
    - Controllability of systems
    - Daylighting
- Innovation & Design
  - Exceptional performance beyond requirement
  - LEED accredited professional

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E. Seven Measures of Organizational Output

Dr. Scott Sink, Virginia Poly (late 1980s) defined measures of organizational performance that could be measured:

- Productivity
- Effectiveness
- Efficiency
- Quality
- Profitability (benefit/burden)
- Quality of work life
- Innovation

- These terms used somewhat ambiguously in everyday life
- These relate to improvement in process, functions and money
- Retain distinction between different stakeholders perspectives

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E. Seven Measures of Organizational Output

1-Productivity: simplest to determine though not for white-collar jobs; defined as (Output/Input) where Output could be quality or quantity and input could be resources consumed

2-Effectiveness: measure of whether the "right" things were accomplished, on time and within specs

3-Efficiency: for white collar jobs it is (resources expected to be consumed/ resources actually consumed)

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E. Seven Measures of Organizational Output

4-Quality: when a product meets a standard, specification or expectation

- unfortunately subjective (ex., automobile)
- difficult to define in absolute terms

Most commonly accepted method in white-collar jobs to determine quality is to conduct surveys

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E. Seven Measures of Organizational Output

5-Profitability – similar to productivity but based on money
= (Total Revenues – Total Costs) / Total Revenues

MOST RELEVANT (bottom line)

Investment in IB based on expectation that profits will increase

Owner perspective- maximize ROI (but keep tenants happy)

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E. Seven Measures of Organizational Output

6-Quality of Life (surroundings, location, parking, ease to get to bldg,....)
- no equations for this measure
- intangibles (essential for tenant retention)

7-Innovation – applied creativity

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E. Relative Importance of Productivity

Bldg Owners and Managers Assoc (BOMA) estimates for a typical bldg:

- Wages & salaries:	$ 150 / sqft/yr
- Bldg/real estate, O&M, energy* :	$ 30 / sq.ft/yr

Total annual cost:	$180 / sq.ft/yr

*Energy $ 2.2/sqft/yr Lighting $1.0/sqft/yr

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E. Relative Importance of Productivity

Simple calculation to illustrate importance of productivity gains:

Case 1: New light monitoring systems decreases lighting costs by 15%

Total lighting costs	- $ 1.0 /sqft/yr
Cost savings	- $ 0.15 /sqft/yr

Case 2: Productivity increases by 1%

Associated cost implications $ 1.5 / sqft/yr

Quantifying productivity gains very difficult because:

- it is intangible, difficult to measure
- relatively small numbers
- but dramatic effect on whole building costs

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E. Difficulty in Quantifying Productivity

Analogy: Computer Numerical Controlled (CNC) Machine vs Standard Machine

Con: costs more, requires higher level of skill to maintain and operate

Pro: better quality products, higher production rate, less wastage

Easy to measure increase in productivity and profitability

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E. Difficulty in Quantifying Productivity

White-collar productivity more difficult to quantify:

- Same tasks are not performed day after day
- Involves thinking, deciphering, creating, discussing, designing,...
- One of a kind type of tasks
- Extraneous factors (type of business, location, work atmosphere, how well run,...)

- Input and output variations are great

- Problem difficult but not impossible

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E. Results of Previous Studies

Boyd (Intelligent Buildings, 1994)- European survey results

90% of respondents reported positive results due to:

- Improved work flow
- Easier communication between companies, functions and individuals
- Reduced disruption
- Improved quality of work environment
- Improved control of attendance

Conclusion: IB provide users with needed organizational gains

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E. Results of Previous Studies

Digital Equipment (Stockholm) and HP (UK) surveys after significant changes in facility and location:

- IB do result in sustainable productivity increases

- Unlikely to exceed 10%

Relates to organizational gains

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E. Results of Previous Studies

CAUTION:

- Bldg is a tool
- Giving workers a tool is necessary but does not guarantee improved productivity

Roach (1991)- Surveyed the American Service Sector:

1982 - investment of $ 6 k/white collar worker in IT

1991 – > $100 billion in IT (85% of installed IT base in US)

Yet, no evidence that this capital investment has increased productivity

Productivity Paradox: Unequalled scientific and technical advances of industrialized nations did not translate into measurable productivity gains !!!

This conclusion challenged in recent years

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E. Summary

Measures of organizational performance can be based on:

- Absolute- compared to similar buildings under similar circumstances (urban, location, size,...)
  - difficult to measure
  - pertinent to design of new building
- Relative – compared to previous years before conversion to IB
  - easier to measure
  - relevant to existing buildings

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F. Future Market Potential

- Very prominent societal drivers
- New technological innovations
- New AI and IT methods
- Increasing number of consulting companies (similar to Green Buildings and Leeds Certification)

  - New buildings

  - Existing Building: Develop proposal for upgrading an existing building in to a more Intelligent Building

Note: There are various levels of intelligence of IB and some systems may be more intelligent than others

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