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Transforming Built Heritage towards Smart Buildings: A Case of Walled City Jaipur, Rajasthan

Dr. Vibha Upadhyaya

[1]Professor, Amity School of Architecture & Planning, Amity University Rajasthan, India

Abstract: ***Purpose: Technology play a great role in development of civilization through various eras. Technology not only influences our business or commercial life, but also our domestic life. The Built heritage of Jaipur is an excellent example of sustainability and energy efficiency with its climate responsive compact design. The recent developments are technology friendly but not the old heritage buildings, thus the heritage buildings need to integrate with new technologies. However, due to lack of appropriate knowledge about the application and benefits of these technologies, people are not able to take its full advantage. The purpose of this paper is to suggest how intelligent building techniques can help in Transforming Built heritage towards Smart Buildings while retaining its heritage character. Methodology/ Approach: understanding the smart building construction techniques and explore the application of smart or intelligent technology to apply on heritage buildings while altering the building structure of traditional Havelis so as to achieve an energy efficient and smart heritage building with least possible damage. Findings: The intelligent building system focus on how the building technologies can evolve to best meet the opportunities and challenges of the future. Though it is considered to be highly complex with high installation cost but it proves beneficial in the long run, as it saves energy with low operation cost. The system is highly advanced and able to collect data from numerous sensors which control the entire building's functionality, integrating all the building services. Research limitations/ implications: Intelligent Buildings (IB) take end user needs for working efficiency more into account than do ordinary buildings. The application of intelligent building techniques should be applied not only to heritage buildings but we could check on how we can apply it to commercial as well as monumental buildings. Practical implication: Knowledge about intelligent building needs to be disseminated to the Architects, town planner, construction industry, manufactures, building owners, actual users and all other stakeholders in the construction industry for their appropriate use. Social Implications: Built form of Havelis has evolved in response to the climate, lifestyle and traditional techniques. However, the current transformation is occurring without proper technical expertise and energy efficiency measures without any consideration for its heritage character. Originality/Value: The fortified walled city of Jaipur was planned more than 250 years ago, but it is still sustaining the increased population due to its sustainable planning techniques. By integrating smart techniques it can go along with modern life style while retaining its heritage character.***

Keywords: Intelligent buildings (IB), Energy efficiency, Built Heritage, building automation, sustainable development

1. Introduction

Earlier, cities were developed to fulfill the need of shelter; food, security and work however, adequate housing combined with well-planned infrastructure and affordable cost provide dignity, security and privacy to the individual, the family and the community as a whole. Traditional settlements, present a physical fabric, which is truly responsive to social, economic, cultural and climatic requirements with an evolved balance between built and unbuilt spaces.

Human settlements are never static and transformations, whether desired or not, do occur at all times. Change is an essential part of sustainable urban development. People alter their building with their changing culture of society and lifestyle with every new generation, once people settle in houses, their use of the spaces and the building fabric depends on their behavioral preferences. People always want to live in an environment that reflects their tastes and values with changing lifestyle.

In this age of technology, everyone wants to be smart and live in a smart environment. And our traditional buildings are also not unaffected with it. The historic precincts having heritage buildings of any city is the nucleus for developmental activities and is always subjected to growth impulse owing to available facilities and easy approach, resulting into continuous transformation. People are installing new services like HVAC, Electrical appliances and willing to make their houses smart. But in absence of sufficient planning and management, this may negatively affect the built environment and may increase the load on infrastructure. We cannot force stop this transformation hence making people aware about technology and their incorporation can help.

A study says that in a smart building (IB) the building fabric, space, services and information systems respond in an efficient manner with the initial and changing demands of the owner, its occupants and the surrounding environment (ARUP 2003). Walled city of Jaipur had been a sustainable city with adequate social and physical infrastructure to accommodate the planned population. With addition of few technology interventions it is very near to become a smart and sustainable city.

In this study, the author is focusing on making the heritage buildings smart. Intelligent buildings concept plays an important role in the planning of future smart buildings, these are the new generation of buildings that more or less think for themselves and are part of progressively more integrated built environment. These Buildings are receptive & adaptive to varying needs of occupants and flexible enough during their life cycle with the help of their architectural design and IT installations.

With these intelligent techniques, building can be operated more efficiently being productive, safe and energy-efficient while creating sustainable environment for the occupants and visitors. It also adds to the marketability or valuation of the building. Intelligent buildings (IB) can cope with social and

technological change and are adaptable to short & long term human needs. It also takes end user needs for working efficiency more into account as compared to standard buildings.

Intelligent Buildings (IB) have less impact on exterior and interior environments as compared to ordinary buildings (Derek Clements-Croome). It can promote sustainable water supply and sanitation system by sensors and other technology interventions. IB's have efficient management of building, and various spaces, enhancing the productivity by creating a comfortable environment. IB's are adjustable and receptive to different uses and spaces ranging from residences, commercial spaces, offices, institutional and industrial buildings. IB system gives information to users about each and every element in the building with help of wireless sensor networks.

Intelligent buildings (IB) provide actionable information about a space within or outside a building (with help of alarm and sensors), to allow the building owner or occupant to manage timely. Intelligent buildings (IB) provide the most cost effective approach to the design and the deployment of building's functional system by integrating all the essential building services and systems. Currently traditional system is being followed while transforming the heritage buildings, in which each and every component of building is designed separately contrasting intelligent building system in which complete building system is integrated.

2. Traditional Havelis of Jaipur

Haveli is defined as the large traditional Indian house having one or more courtyards. The climate of Jaipur is hot-dry with dusty summers and moderate rainfall and Courtyard planning, Big windows with low sill and High ceiling is provided to support ventilation and increase comfort levels.

The dwellings of the past, which provides us with a rich fabric of experiences, bear witness to such efforts, one may feel a sense of wonder while looking at these dwellings and finding in similar climates elements which have been discovered as a result of the human efforts to control the climate environment. Traditional buildings are the reflection of the life style of the local people. These buildings were made with the technology developed at various stages of civilization.

While planning the traditional settlements and buildings, extreme climatic consideration was given to the use and of open spaces, water bodies, construction material, built form and treatment of facades of buildings. The open spaces are quite significant in the social lifestyle of the people forming the meeting spaces and are center of activities during the different times of the day. The water bodies thus became coherent with the open spaces and the much required lung spaces for the city contributing in keeping the climate cool, and acting as a node for their social and cultural activities. This system is used in almost all the traditional settlements of Rajasthan and other parts of India.

It is a fact that we need to adapt with the upcoming generation and technologies to live a sustainable life. The definition of sustainability also refers to the fulfillments of needs of our future generation without compromising the present needs. This study emphasize on inclusion of new technologies in our existing buildings, without much disturbing their original character.

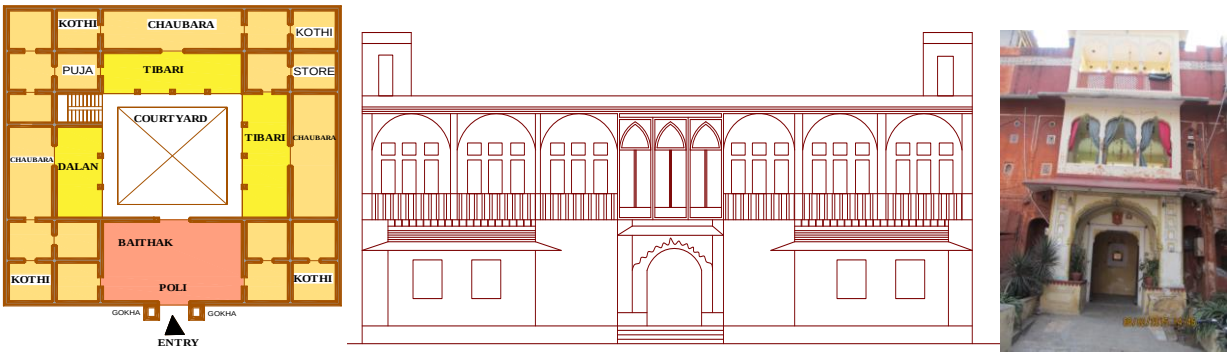

Figure 1: Plan elevation of a typical haveli in walled city Jaipur (Author)

A. Transformation in Havelis

Transformations take place because of urbanization, modernization, economic pressure, natural disasters, political instigations, cultural & economic changes and other circumstantial reasons. In addition, resident population is not transient and people tend to transform the places they control. Once people settle in houses, their use of the spaces and the building fabric depends on their behavioral preferences. These transformations can be attributed to the fact that people always want to live in an environment that reflects their tastes and values. But in absence of planning, this happens in a haphazard manner without any control and may negatively affect the built environment and the quality of living conditions of the residents. In walled city Jaipur also, lot of transformation took place in the use and structure of building viz; at some places, the original havelis owners moved out, with decline of the joint family culture, resulting subdivision of Havelis in to various nuclear family units. Some of the residents rented their properties, some people sold their portion to somebody who does not have interest in heritage and some changed the use of havelis in to commercial business. Many of the havelis are converted in to wholesale commercial business or storage go-downs.

To accommodate the different purpose base on their lifestyle People are doing alteration in havelis. For commercial use people are altering Havelis for retail or wholesale convenience and for residential use alteration are happening

to accommodate the growing population and changing lifestyle. . These transformations are happening without proper technical expertise and energy efficiency measures. Further, the changing life style and building use pattern has attracted the use of artificial or Mechanical lighting & ventilation and its unplanned installation has overtaken the natural energy efficiency of building. The appliance and building system is disintegrated leading to misuse of energy. As a result of that, load on energy and infrastructure is increasing and creating lots of environmental issues.

Although there are some buildings regulation to protect the heritage of walled city like the design, material & construction techniques of the new construction or structure or works shall not disturb the harmony and heritage character of building etc. but people are not able to follow this because they are not aware of appropriate techniques and they are willing to transform the buildings. The building automation techniques can transform the building without hampering its heritage character. It is necessary to conserve the built heritage and maintain its significance because it gives distinctiveness, meaning and quality to the places in which we live, providing a sense of continuity and a source of identity. This study explores the application of intelligent & energy efficient building technologies while altering the building structure of these traditional Havelis. With these transformation activities, it will be easy to apply intelligent building techniques, as people can integrate these techniques easily in to their renovation planning.

B. Potential of traditional Havelis to become Smart building

It is easier to make a new building intelligent than revamping an existing building. For a new building, all necessary inclusion can be done right for the building life cycle as it is easier to work on conduit, wiring, fixing equipment and sensors to implementation and integration in an upcoming building. On the other hand there is multitude of challenges in integrating intelligence into an existing building. Introducing new architectural elements or any modern techniques into a traditional Havelis is a challenging task that too without interfering with its original design is a task. (A.l. pisello et al) As laying new set of cables, fixing sensors, integrating with centralized management consoles and IT systems need immense planning and effort. At times, it might also require some structural modification. This concern is somewhat balanced by energy-saving qualities already present in many heritage buildings that reduce the need for alterations. Heritage buildings in the study area are aesthetically appealing and inherently energy efficient owing to their compact design and climate friendly planning. Hence Before adding any new component or techniques in these heritage buildings, it is important to analyze the effects of modifications on Structure of building and visual impact on its heritage.

When doing some technological improvements to historic buildings, protection of the historic property's materials and features, for Rehabilitation to ensure that the architectural integrity of the historic property is preserved, retrofit project goals of for energy efficiency with the least impact to the historic building etc. A sample survey was conducted in walled city by Author for collection of data to analyze consumption of energy in traditional buildings and outlook of owners for transformation. As per there electricity bill, the energy consumption ranges from 10 KW to 200 kW per day. There was a large portion of high income people having large Havelis with 4-5 storey havelis, who were interested in techniques of intelligent building for many fold reasons viz;

- They wanted to reduce their electricity bills
- To achieve comfort condition in house
- Wanted to keep pace with modern life style
- Sometimes people forget to switch off the light, fan or any other electrical equipment's, before moving to upper floors or any other place and it will remain on until somebody comes back
- They needed a lift in their house as it was very difficult for elderly and handicapped people to travel upstairs, also staircases are so narrow that it is not possible for other person to hold and move the needy in staircase.

Due to all these reasons homeowners were interested in building automation, so that, with help of sensors, actuators and other automation techniques all electrical equipment will be automatically switched off when not in use.
However, before discussing about the application of intelligent techniques in heritage buildings, it is essential to know the basic system of intelligent buildings (IB) which is explained in further section.

3. Intelligent Building (IB) Techniques

Intelligent buildings(IB) Techniques are controlled by Building automation system which is an example of a Distributed Control System (DCS), it is a computerized, intelligent network of electronic equipment, intended to monitor and control the lighting, HVAC, safety & security, Communication network, other mechanical system and facility management in a building. An Intelligent Building (IB) involves the installation and use of advanced and integrated technology system for buildings. It is equipped with special structured wiring to enable occupants to remotely Program or control the array of automated electronic devices at home by entering a single command. It is Equipped with sensors and actuators for direct or indirect input and manipulation of signals from users, systems & building structure. It carries out 'intelligent' behavior viz; self-diagnosis, activate actions on certain events and Integrate different systems to form complex systems(R. J Robles, T.h. Kim , 2010). These buildings keep a watch over themselves and their own wellbeing. In addition, the automatic system puts off lights & shutdown air conditioners when not in use, checks the water storage tanks, and leakage in the pipeline, it also triggers the alarm in case of fire and recharges the central UPS (Uninterruptible Power Supply) whenever there is a power failure. Intelligent buildings (IB) can help to provide Optimal lighting level, reduced energy use, increased security and increased efficiency, Operational and Energy Cost Savings in traditional as well as new buildings.

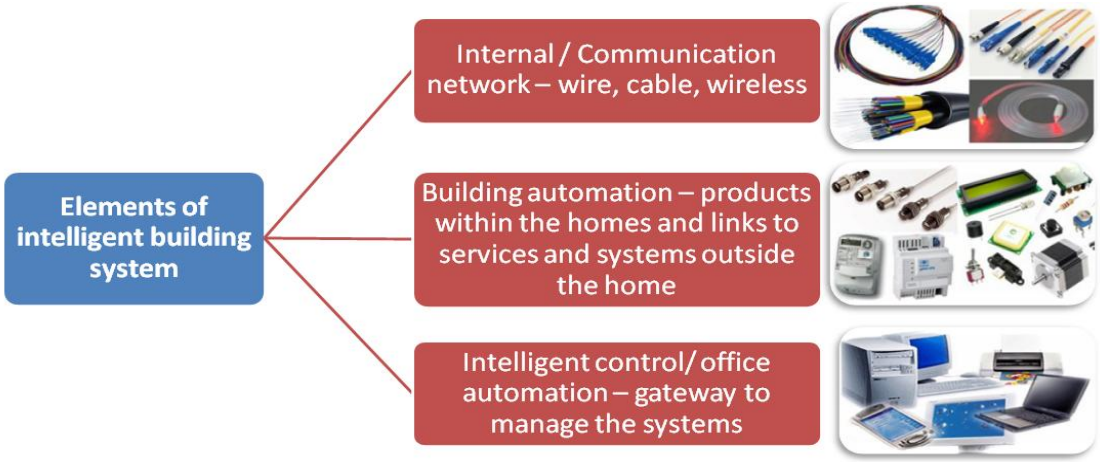

Figure 2: Elements of intelligent building (IB) system (Compiled by Author)

Building Automation: A building automation system incorporates a communication network which connects the key electrical equipment's and services in a building to control, monitor and access them remotely. Intelligent Building (IB) are one where the combination of technologies and interconnected systems supports the use of the accommodation by the building's users, enables the efficient operation of the building and enables reconfiguration of the space in response to changing use. It is the integration of systems which support or manage the building environment, space and operational systems. An Intelligent Building (IB) is equipped with a special connected platform enabling its occupants to remotely control and program an array of automated electronic devices (Arthur D little, 2012).

The key Components of automation system in intelligent buildings are internal or communication network, building automation, intelligent control or office automation. This provides a comfortable, efficient, reasonable, safe, and convenient living and working environment.

Internal **Network:** The infrastructure convergence is typically achieved through the use of a common cabling and/or wireless infrastructure, supporting IP (Internet Protocol) based networks within the building. There are mainly four types of internal networks that can be installed in a new or existing building to support the intelligent technology.

Table 1: Types of Internal network

Internal Network	Details	Suitability
Structured wiring	It involves running specialized high performance cabling throughout the building and provides a highly reliable and secure network, which communicates data signals for phones, computers, TVs and audio components.	Suitable for new building, in case of existing buildings it may need some structural modifications
Wireless networks	It provides the advantages of mobility and flexibility in a building while virtually eliminating the wiring complication faced by ordinary buildings.	Suitable for both new & existing building
Power-line networks	It uses the building's existing electrical lines to transmit data. This is relatively easy to set up and operate but it is relatively risky for power surges, also neighbors can share the network on same transformer.	Suitable for both new & existing building
Phone-line networks	It use a building's telephone lines to carry different operation, each service is assigned a unique frequency spectrum to stop inference between two activities	Suitable for both new & existing building

Compiled by Author

Building automation: The Building automation system's core functionality reduces building energy and maintenance costs when compared to a non-controlled building. Building automation can optimize efficiency of HVAC by adjusting the start/stop times for occupied periods, keeps the building climate within a predefined range, switching off/on lighting based as per occupancy and monitors system performance. It sends email and/or text notifications in case of device failures. It accomplishes the automatic control of inner building equipment, with the help of sensors to collect data, which can be sent to the intelligent signal acquisition of the equipment, to complete automatic control. It consists of central administer station, controller and sensors to complete a variety of control and management function of network

system. This system includes devices like sensors, actuators, controllers, buses and other interface.

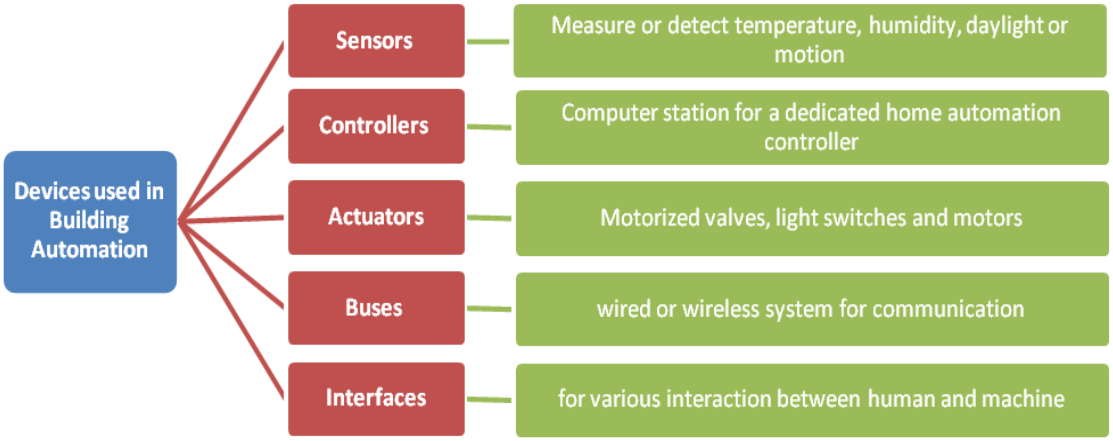

Figure 3: Devices used in building automation (Compiled by Author)

Integrated Building Automation: Building automation and control systems are the building's brain. They integrate the information for all the building's technology and control HVAC, lighting, fire protection, blinds as well as security systems. The building's brain is thus the key for an effective check of energy use and all ongoing operating costs. Existing heritage buildings can be operated at significantly lower energy use after updating building automation and system functions that are optimally set and activated result in Cost savings from operational energy, conserve the environment and existing energy resources and Guarantee reasonable comfort during occupancy of existing heritage building. The Typical Approach to Automation for Buildings can be categorized in three ways

- Non-Integrated Building : ordinary building without any automation
- Partial Integrated Building : buildings with partial automation (Suitable for existing heritage building)
- Fully-Integrated Building :building with complete automation

Table 2: Types of Building automation

Ordinary Building	Partial Integrated Building	Fully-Integrated Building
• Stand Alone Systems • No Technology Integration • No documentation for performance of equipments • High costing for up gradation and O & M Cost	• Single User Interface for all Systems • Software Integration on IP networks • Permits Development of integrated database • Database Permits Management of Energy, Assets and Maintenance Management etc. • **Suitable for application on Existing Buildings**	• Open Standards Applied Where Possible • Number of Devices Reduced due to Shared Information • Open Control Networks Promoting Competitive Bids in each Building • Integrated Building Sub-systems • Lighting, HVAC, Power Management and Security • Suitable for New Buildings or building which can afford major alteration as existing building may need more retrofitting.

Compiled by Author

Although, in fully integrated buildings the values is increased due to advancement of information technology and Updated information may prove to be a competitive advantage. But Buildings in walled city are currently fall under nonintegrated category, as there is no automation. For existing buildings of walled city full integration may need lot of renovation and construction which can harm the heritage of city. The occupants of these buildings want high technology with intelligent system but the heritage laws and culture do not allow damaging the building heritage, allowing minimum alteration. In addition, the cost of full automation in existing buildings can be more costly as compared to partial automation. Hence for these heritage buildings, partial integration is suitable, as it will need less modification as compared to fully integrated buildings.

Intelligent control: A control system saves a lot of energy. Lighting controls reduce unnecessary artificial lighting via motion sensors and schedules as well as by controlling daylight-harvesting louvers. Remote network monitoring and troubleshooting via the Internet reduces service calls. Control systems provide smoke control during a fire while maintaining a breathable environment for evacuation as well as natural ventilation. Controllers in particular, provide optimal zone ventilating, heating, and air conditioning, based on sensor input (KMC Controls, Inc.).

4. Intelligent building techniques for Heritage Buildings

Intelligent Buildings (IB) supports the increasingly integrated built environment; it is viewed as a provider of responsive, effective and supportive environment within which anybody can meet its performance objectives. Heritage buildings of Jaipur are already climate responsive in its original form and considering integrated Intelligent Buildings (IB) techniques while change in energy use and other transformation can create environmentally responsive design considering the surrounding area and building usage while involving the selection of appropriate building services and control systems to further enhance building operation with a view to the reduction of energy consumption and environmental impact over its lifetime.

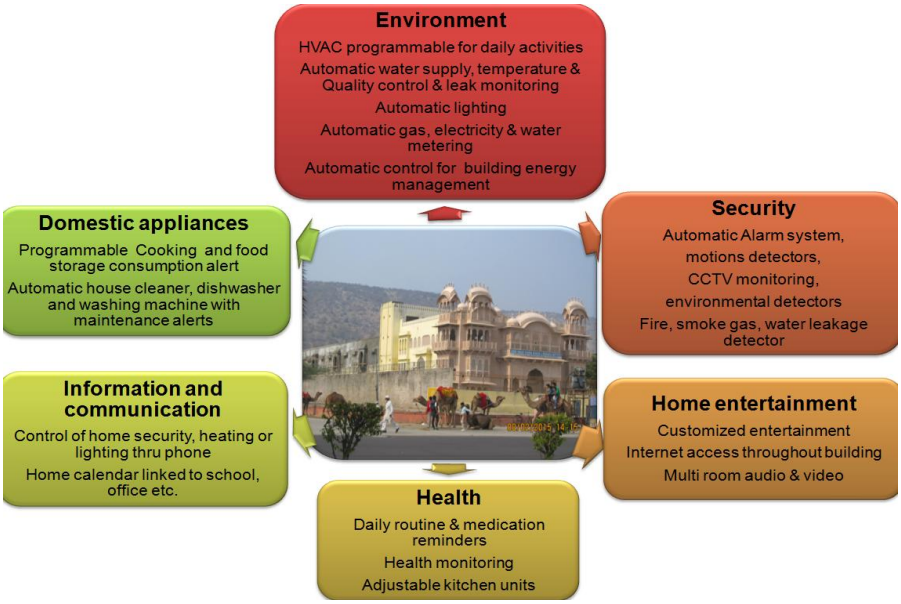

Figure 4: Services & technology integrated in an intelligent building (Compiled by Author)

There are basically six main Services in a Heritage building where intelligent building techniques can be applied viz; Environment, Security, Home entertainment, Domestic appliances, Information and communication & Health.
All these techniques provide user friendly and customizable options with greater comfort and increased efficiency with quick and, flawless technical responses to human interaction.

Thermal and electrical energy should be kept to a minimum to achieve a high degree of energy efficiency. As per the chart below, Buildings account for about 41% of primary energy consumption, which is a significant portion (The World Bank data 2008). According to the World Bank data of July 2008 the average energy consumption by buildings and average Indian house hold, is shown in following charts.

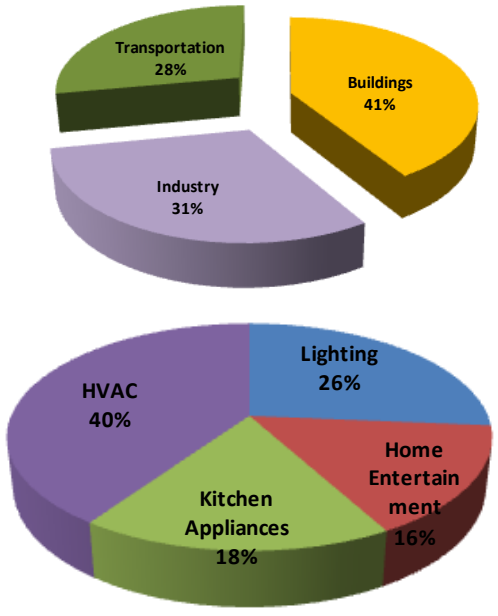

Figure 5: Energy consumption in buildings [The World Bank 2008]

As per the above data, currently HVAC accounts for maximum i.e.; 40% of household energy consumption, making it the largest energy user in the average Indian home. The appliances include electric water heater or geysers, fans, air coolers and air conditioners. Lighting is the second highest for electricity consumption about 20-25% of electricity. Other than HVAC and lighting, kitchen appliances like fridge, microwave, induction, food processor etc, and house hold and home entertainment appliances like TV, home theatre, radio, set top box, computer, phone etc, consumes about 1/3rd of household energy. However, all power devices are not ideal as Most of the kitchen and home appliances draw standby power; thereby dissipating energy leading to power losses which can contribute up to 10% of electricity while when not in use(EU2 analysis GOPA).

In building automation, sensors are inserted into Walls and ceilings of heritage buildings to measure its performance. Software tools automatically optimize the building systems without human intervention and Information relevant to particular needs of occupants and building management is provided. Heritage Buildings can be connected to power grid and GPS systems can be deployed for every building asset.

A. Case Study for IB Application

To support this, one of surveyed Havelis is taken as example; this is one of the surveyed Haveli. It belongs to high income group people, who are willing and have potential to develop it as intelligent building. This Haveli is located in Chowkry Ramchanderji in walled city Jaipur. The Haveli is a G+4 building, having total built up area of 1200sqm, owned by a Jewelers family. The Haveli is planned in typical courtyard pattern, with three courtyards. Most of the rooms in Haveli are having good light and ventilation with provision of many opening in the form of windows, Jalis (perforated screens) & courtyards etc. This Haveli is subdivided among three brothers, in the form of a fraternal cluster, with collection of 3 single courtyard Havelis, each belong to one brother, opening in to a common forecourt. Since all the brothers' handled the family business, it was an efficient layout. However, Out of three families, only one family resides here and rest of two families shifted to outside areas.

Figure 6: Plan, Elevation and section with external views of studied Haveli (Author)

The portion is completely occupied for commercial purpose; either owned or rented, except reserving a small residential unit. The commercial used includes Office, Retail and storage space. Road side rooms are being used for shops and inner for storage while upper floors are being used for office and other business purposes.

Further the calculation is based on analyzing electricity consumption before and after applying building automation and its economics. The average electricity consumption for the portion of family residing there is about 4000 (KWh) Units. Many of the internal rooms are dark, requiring light as and when needed. Due to G+ 4 heights, it is difficult for the family to keep a constant check on electric items like fan, light, AC etc.

Smart or Intelligent Buildings (IB) are now part of an integrated built environment, which is viewed as a provider of responsive, efficient and encouraging environment within which anybody can meet his performance targets. The current technologies focuses on development of climate responsive buildings with use of appropriate high technologies, which will have low environmental impact on external and internal environments and will have sustainable water and sanitation system.

Figure 7: internal Views of transformed Commercial spaces and other opening in the haveli (Author)

Intelligent building techniques are important while designing new buildings or renovating old structures, as applying any modern technique to an existing building is a complicated job as compared to new building. Especially in case of building having any heritage importance it requiring utmost care and attention. A lot of transformation is already happened in this Haveli viz; rooms are converted in offices with fitting of AC and other modern appliances, inner rooms are being used for storage and this transformation is continuous. During the case study the owner and his family interviewed and they seem interested in applying intelligent building techniques, as they need these changes in their building system and automation could have sorted out their many issues while reducing the energy consumption. They were keen to know about the techniques involved, cost associated and its feasibility. Also it was an effluent family who could easily afford the expenses. But there are other Havelis for whom the cost feasibility can be an issue, Hence in further section the cost of building automation is calculated.

5. Energy saving in Building Automation

Building automation basically allows the optimization of energy required for the support functions of a data center in which Power to Secondary Support such as cooling and air-conditioning of control room etc, can be reduced. Data center is a system or organization which includes all of the equipment to support information technology for building automation.

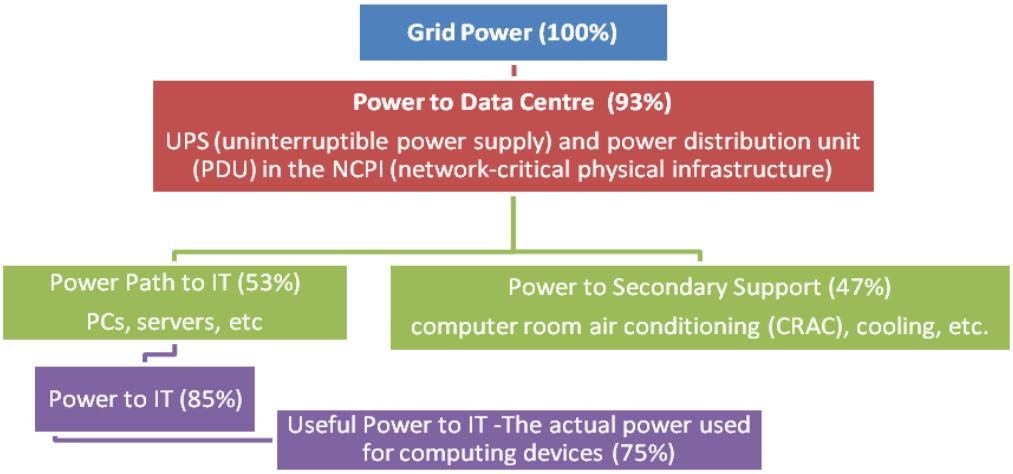

Figure 8: Process of energy saving in Building Automation process of energy Transfer from data center to equipment [CABA 2013]

Above chart shows how energy is saved while transferring from data center to devices. Building automation enables the re-distribution of the % of the total power to the data center which is further divided in IT path and secondary support. For example, in a 100 KW capacity data center, the energy consumption and Losses of power in an ordinary and automated building will be as follows.

Table 3: Power calculations at several stages in a typical data center (100KW) with or without Building automation technology

		Ordinary system	Building Automation	
A	Grid Power, kW	107.41	98.15*	*The power requirement for secondary support is reduced with building automation and after keeping the useful power to IT as same, the power is redistributed reducing power drawn from grid source
B	Power to Data Center, kW	100	91.38	
C	Power Path to IT, kW	53	53	
D	Power to Secondary Support, kW	47	38.38	
E	Power to IT, kW	45.05	45.05	
F	Useful Power to IT, kW	33.79	33.79	

Source: Juan r. Pimentel, 2009, Energy and Building Automation a white paper on its potential for the city of Flint and Genesee county Alt Energy Inc

For a typical 100 kW data center, the useful power for IT is 33.79 kW. Hence for an ordinary building without automation the overall efficiency is (33.79/107.41) = 31.45%, while for a building with automation (after redistribution) the overall efficiency will be (33.79/98.15) = 34.43%.

The above calculation clearly explains that the power used in ordinary and intelligent building is same but there is a difference in drawn power from grid, it is higher in ordinary system and much lower in building automation. Hence, a saving of (107.41 – 98.15) = 9.26 kW per 100 KW is achieved [CABA 2013].

Further this is the case for new buildings which are designed according to modern concept integrated with all mechanical systems. But in case of traditional building energy saving can be higher as these are designed to take full advantage of natural climate. But increasing unplanned installation of HVAC and other electrical equipment are not able to take advantage of natural light and ventilations as in the existing scenario in walled city Jaipur. If these traditional buildings take advantage of natural lighting ventilation along with building automation, it can increase energy efficiency and saving on electricity bills. The building automation system can save more than 30% of energy [Siemens 2011].

6. Costing of Building Automation

Life cycle cost of Existing building includes a major component of operation and maintenance, on average only 25% of a building's costs incur in its construction, while the remaining 75% of the costs involves the operation, Maintenance and up gradation in the building[CABA 2013]. The traditional buildings are constructed in older times; hence their O & M cost will only be counted for life cycle assessment. As per primary survey people the family spends about 8000 to 1000 Rs per month for maintenance, up gradation and repair.

The costs for building automation, basically involve the cost of performing the all energy saving activities and equipment costs including computers station, Bus Terminal - I/O (Input/output), Bus Terminal Controllers, sensors, actuators, Electric Switches, conduit, boxes, Ethernet, Web Servers etc, interconnected by one or more communication networks of type wired or wireless. Life cycle of building automation with proper operation and maintenance is more than 15 years [Control Solutions Inc.]. The life cycle cost of building automation is as follows in table 4:

Table 4: Life cycle cost and payback calculation of an intelligent Building

Annual electricity bill	288000	Average Monthly bill 4000 KWh. Approved tariff for 2014-15 @ 6 per unit (RERC) [Order no. 203, Tariff Regulations,2014,RERC]
Annual Savings		
Annual Saving on electricity bills @ 30%	86400	
Annual O & M Cost for Ordinary Building with similar area (@ average 8000 per month)	96000	
	182400	
Life Cycle Cost Component		Cost (INR)
Cost of Building Automation including equipments and installation (@Rs 250/Sqft)*		1000000
Operating & Maintenance (10% reduction in O & M cost of ordinary building)		86400
Total Life Cycle cost		1081600

Payback calculations

Payback period	= 1080000/120000 = 5.92 ~ 6 years

*Source : Primary survey of Buildings and rates from automation vendors (* as per Market survey the per sqft cost of intelligent building ranges from 150 to 300 Rs for New Buildings and 250 to 400 Rs for Old Buildings) with O& M is reduced by 10%from ordinary Buildings.*

Here Simple payback does not reflect full value as it provides only a tentative saving that could accrue in the early years of a project. Initial costs and expected annual savings do not reflect variances in expected equipment lifetime. Additionally, maintenance cost differences, periodic rebates and incentives, as well as other operational savings that could accrue beyond initial years has an impact on total cost of ownership. Other than payback period Intelligent Buildings (IB) have many benefits like:

- Improve interdependency between building systems and users
- Provide a healthier and more comfortable environment
- Increase economic performance
- Reduce energy and resource usage
- Benefit from renewable energy technologies
- Augment indoor air quality and occupant satisfaction.

However, in older buildings, intelligent building techniques can help users to determine specific component requiring maintenance, up gradation or replacements, which generates the greatest return on investment.

7. Energy Efficiency Techniques

Before implementing any new techniques, the existing energy-efficient characteristics of a historic building should be assessed. The design, materials & construction techniques, landscaping, and climatic condition plays an important role in buildings performance. Traditional buildings are constructed with response to local climatic conditions, maximizing the natural sources of lighting, heating and ventilation. Whether rehabilitated for a new or continuing use, it is important to utilize the historic building's inherent sustainable qualities as they were intended to ensure that they function effectively together with any new treatments added to further improve energy efficiency.

Windows, courtyards, and light wells etc., which provide natural ventilation and light can reduce energy consumption. Whenever these devices can be used to provide natural ventilation and light, they save energy by reducing the need to use mechanical systems and interior artificial lighting.

The typical havelis design of Jaipur is compatible to the climatic conditions as well as social conditions. The built form is very compact in its structure and suited to the hot dry climatic conditions. The houses or Havelis have an introvert plan around a courtyard. The treatment of the facades and openings indicates a sensitive response to climatic conditions. The closer knit structures help to reduce exposed surface area of building to harsh sun and therefore heat gain of a building gets reduced. The spaces between building form narrow lanes which protect the pedestrians for most of the day from sun.

The walls and roofs are having good thermal resistance to protect from hot climate. The sizes of openings on outer face of buildings are small to cut out harsh sun and hot winds. An important feature of the buildings in these walled cities is their porosity; a Havelis is full of openings. These openings are different in size, from small windows, finely carved stone jails, Jharokhas and courtyards and which allows passage for through cross ventilation. However, due to unplanned subdivisions and construction activities this concept is vanishing day by day.

Although intelligent building techniques reduces the energy consumption but to operate the electrical and other automatic appliance use of energy in the form of electricity is must. As we are very much aware that current non-conventional energy sources are depleting day by day hence Use of renewable energy sources is also very important. The conventional sources are non-renewable and once they exhaust, they will not be replaced. The reduced availability of these non-renewable resources will also result in a significant rise in energy prices. The availability of local renewable energy sources reduces dependence on conventional sources. Use of these conventional sources emits the greenhouse gas into the atmosphere, which is not the case with renewable energy sources, making them better choice for the environment improvement. Integration of Renewable energy resources viz; solar, wind, geothermal, and biomass & Hydro. The electricity generated by these renewable energy sources can be easily store and transfer to national grid with intelligent techniques of Smart grid.

The article further also focuses on use of energy efficient & sustainable techniques with generation of energy thru renewable energy resources. It is always point of concern for everybody that before installing any energy efficient or renewable energy techniques in a building, all energy consumption shall be reduced or cut down, to improve its energy efficiency & to reduce heating and cooling costs. Energy is used in buildings for various purposes like heating & cooling, ventilation & lighting and the preparation of hot

water, installed equipment and appliances and removable devices like mobile phone chargers and portable computers consume energy. Also the electricity meter measures the total amount consumed by the whole building, and identification of fixed and fluctuating demand for different energy equipment is rarely known. Hence, measures should be undertaken first to save energy in any existing building particularly for historic buildings; some common measures are as follows:

- All the Public as well as private entities should comply with the provisions of energy saving codes & Byelaws.
- Awareness campaign for energy saving and sustainable development need to be conducted with the help of visual or print media, school education, manufactures etc.
- Use of energy saving devices like CFL's, LED's and five star rating equipment
- Regular cleaning & maintenance of all energy consuming equipment's viz; cleaning of tube light, bulbs, electric kettle and microwave, manual defrost of refrigerator, cleaning of air-conditioner filter etc.
- Repair and maintenance of cracked or damp building components.
- Use of automatic shut-off button equipment's.
- Turn off the electric devices when not in use.

Intelligent building techniques very efficiently complete this task by automated control with few operation changes. As we have already discussed above that, the key elements of IB system are internal or communication network, building automation and intelligent control or office automation. In these element Building automation and intelligent control does not require any major structural changes. In the internal communication network, structured cabling system of fiber optic and copper structured cabling may need to install throughout the home in the form of electric lines or phone lines for connectivity with the help of sockets.

An open structure cabling system has existed for years and gives the customer greater freedom to mix and match data systems. Many manufacturers design their systems to operate across open structured cabling infrastructures, which is very suitable for existing buildings. Devices can be looped or chained according to the particular system requirements. The Information Outlets Sockets and display monitors can be mounted on walls, pillars or ceilings. For devices which are designed to connect in a bus or loop system, extended Coverage Area wiring is suitable. Also devices can be chained or looped together from or between outlets, instead of having separate outlets for each device. Additionally, fault tolerant device wiring may be use for immediate detection.

These Havelis have thick walls made of sand stone with dry masonry. And all these have lots of opening in the form of small windows, Jalis, Jharokhas and courtyard spaces. The structured cabling can be routed thru these opening throughout the building. Also as walls are very thick small alteration near wall skin to accommodate the cables will not affect the structure. Also since it will be internal, it will not impact the elevation feature and heritage element on external façade of the building.
Other than structure cables, the equipment's need to install in Intelligent Buildings (IB) are mainly Energy meters, energy switch and actuators, gateway or light controller, sensor devices, detectors, Display monitors and inverter batteries etc. All these devices required similar spaces as we have in our existing electricity systems. With the current transformation and retrofitting in Havelis, these systems can be easily adapted and our traditional Havel is can become Intelligent Buildings (IB) whether it is under residential use or commercial use.

However, wherever it is difficult to put structure cabling we can also use wireless technology and it can be complemented by the use of wireless systems, with Wi-Fi being deployed throughout the building. For the smart sockets or switches existing electrical switches and points can be replaced very easily without any major structural modification.

8. Findings

Traditional buildings are constructed with response to local climatic conditions, maximizing the natural sources of lighting, heating and ventilation. A judicious and planned integration of building automation techniques can create a comfortable environment by adjusting the functional aspects of building such as air conditioning, ventilation & lighting etc. In addition; the security & communication system of building can be coordinated and controlled by this. An Intelligent Buildings (IB) has lots of advantages as compared to any ordinary buildings such as:

IB's are very Energy efficient as less power is consumed as compared to ordinary buildings and contribute to low carbon emission being **Environment friendly**. It will save energy in heritage building by auto operating electrical equipment's as and when needed.

It also benefits the occupants Health in the form of Life safety enhancement; timely notification and sending information to occupants for undertaking appropriate actions. The passages and staircases in traditional buildings are narrow, restricting timely escape in case of emergency. Therefore, timely notification by automation can benefit in emergency

Operating cost is significantly lower as compared to ordinary buildings, some smart home technologies are not only convenient, but they also save money on electricity bills and maintenance. Intelligent heritage Buildings can increase efficiency and productivity with low operational cost.

Easy installation: In heritage buildings, major alteration with skill workforce can be required for installing wired connections but wireless device needs very few alterations. Many technologies of Intelligent Buildings (IB) are compatible with wireless devices and can be installed with minimum expertise easing the installation.

Customization: the heritage Havelis varies in scale and typology; there are different spaces with in Haveli from open semi and closed type which need customized products. As IB technology is not limited to one type of product; programs are customizable. We can customize our smart home as per our choice.

Convenience of having all building products programmed to occupant's specific needs is a true luxury that comes with living in the current digital age.

In spite of all these advantages there are also some **disadvantages** of intelligent building systems such as:

- **Expensive technology: Installation of** intelligent building technology is expensive as compared to any ordinary heritage building.
- Sometimes, software programming is too complex and time-consuming which make difficult to perform the task compared to traditional way.
- **Sometimes, t**he wireless signals for IB's technology can be interrupted by complex electronic devices such as televisions and computers, and this can lead to weak signals and erratic operation.
- The integrity of the building may be compromised if third parties gain access to our critical building systems control. Disabling security and access control could put lives at risk and necessitate personnel being redeployed to implement manual checks in place of the automated systems.
- Intensive use of internet and IT based system can attract increasing risk of cyber-attacks and hacking etc.

Today's smart buildings are controls the entire building's functionality, including heating, ventilation, air conditioning (HVAC), lighting systems, and often water, fire and life safety. Beyond integrating all these separate functions, modern technology is now highly advanced and able to continually collect millions of data points from numerous wireless sensors and meters. This sophisticated monitoring system significantly improves a building's energy efficiency.

9. Conclusion

A few years ago these concepts were considered futuristic and fanciful. Nobody could have imagined that these old heritage Havelis can be a smart and technology friendly building; these havelis are 4- to 5 storey high without any lift system, which is now creating inconvenience to occupants. Operating the electrical equipment's at different floors was not an easy task. But now they are reality, where different systems in a building communicate with one another through the control system, thereby enabling single button and voice control simultaneously, in pre-programmed scenarios or operating modes.

Though the intelligent building system is very complex and installation cost is also high but in long term it is beneficial as its saves energy and its operation cost is very low. It can provide many benefits to a person or business by integrating a number of operations for most efficient use of their building systems which will ultimately increase the potential and productivity of building and its users.

Integrating the building automation techniques in heritage buildings will not only save the energy but also will improve the quality of life of occupants. Installing the intelligent building techniques will need a thorough survey of building and planning in advance. This survey and planning before installation and refurbishment will not only improve the efficiency of building but also will protect our built heritage.

The need for healthy, sustainable and responsive environments is a global concern. Knowledge about intelligent building needs to be disseminated to the Architects, town planner, construction industry, manufactures, building owners and users.

Intelligent Buildings (IB) are a relatively new and evolving area, so there is a need for building owners and occupiers to ensure that the associated risks are fully understood and addressed throughout the building lifecycle. Wi-Fi is susceptible to interference, jamming & Hacking and should be avoided in safety-critical and security systems. Life cycle of buildings and intelligent systems need to be assessed for long term use and compatibility.

The development of intelligent building systems in heritage buildings focuses on how the building and its related technologies can evolve to best meet the opportunities and challenges of the future.

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Author Profile

Dr. Vibha Upadhyaya is an Architect Planner by Profession. She is working as Professor in Amity School of Architecture and Planning, Amity University Rajasthan. Her interest area for research includes Architecture, planning, sustainable development and smart cities.