BIM and sustainable design

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Contents

- Environmental impact & architecture
- Sustainable design with BIM
- BIM supported analysis
- Environ & economic aspects
- Analysis tools & workflow
Three dimensions of sustainability

**Environmental Sustainability**
- Ecosystem integrity
- Carrying capacity
- Biodiversity

**Social Sustainability**
- Cultural Identity
- Empowerment
- Accessibility
- Stability
- Equity

**Economic Sustainability**
- Growth
- Development
- Productivity
- Trickle-down

**Environment**

**Economy**

**Society**

**Human Well Being**
Environmental Impact of Buildings

More people live in urban areas than in rural areas
40% of global raw materials is consumed by buildings
We are running out of fossil energy sources

„Our generation must be committed to the task of bringing urban areas into balance with the natural environment.”*

*United Nations Environment publication, World Environment Day 2005

(See also: Environmental Issues & Building Design https://sustainabilityworkshop.autodesk.com/buildings/environmental-issues-building-design)

(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)
Environment and Architecture

Historic Overview:

**Traditional architecture:**
protective, resists external impacts, small windows

**Modern architecture:**
large windows, insufficient construction technology, large energy consumption, bad indoor climate

**1980s:**
counter-balancing bad indoor climate with air conditioning and heating

**Sequential Design Process**
design disciplines do their job one after the other

(Source: Graphisoft BIM Curriculum [http://www.graphisoft.com/learning/bim-curriculum/]())
Environment and Architecture

Historic Overview:

1973-74 energy crisis: energy overconsumption becomes an issue

Building energy research: study and simulation of energy currents through the building envelope

Sustainable buildings: minimal environmental impact design, construction and maintenance

Simultaneous Design Process activities of design disciplines overlap to optimize efficiency and save time

(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)
Architectural Design Guidelines:

- **Functional**: constructional, operational
- **Human**: safety and security, health, comfort
- **Cultural**: aesthetics, social context
- **Ecological**: energy use, energy sources, building materials, water management, waste and pollution management
- **Economical**: profit, life cycle cost

Sustainable design with BIM

- Sustainable design considerations:
  - Understand climate, culture and place
  - Understand the building typology
  - Reduce the resource consumption need
  - Use free local resources and natural systems
  - Use efficient man made systems
  - Apply renewable energy generation systems
  - Offset negative impacts

Sustainable Design Disciplines

- Sustainable sites
- Water efficiency
- Energy and atmosphere

- Materials and resources
- Indoor environment
- Innovation in design
- Regional priority

(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)
Sustainable Design with BIM

Building Information Modeling

Intelligent building model (virtual building)

(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)
Sustainable design with BIM

- BIM advantages include:
  - Ability to analyze
  - Ability to evaluate green buildings
  - Access to info to make sustainable decisions

- Performance analysis & evaluation
  - Merge of design & analysis = optimize building performance
  - Better quality of data = minimum errors and miscalculations
Sustainable Design with BIM

BIM as Collaborative Foundation

- Sharing and exchange of BIM information e.g. to execute simulations
- Strategic cooperation between software vendors

(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)
Sustainable design with BIM

- BIM enables sustainable design analysis
  - BIM provides important data and information for design projects and also encompasses several important functions for building performance and sustainable design analysis
- Common software tools:
  - Autodesk Ecotect
  - Autodesk Green Building Studio (GBS)
  - Integrated Environmental Solutions (IES) Virtual Environment (VE)
BIM and Building Performance Analysis (BPA)

- Visualization
- Structural analysis
- Cost
- Documentation
- Fabrication/Construction
- Etc...

Building Performance Analysis (BPA)

Whole Building Energy Analysis
- Conceptual Models
- Detailed Models

Energy Analysis Model (EAM)

Other Performance Studies
- Lighting & Daylighting
- Sun & Shadows
- Solar Radiation
- Climate Analysis
- Airflow & Ventilation
- Lifecycle Analysis

Sustainable Design with BIM

BIM and Energy Software Collaboration

(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)
Sustainable Design with BIM

BIM-Integrated Energy Simulation

- Model geometry analysis
- Additional data input
- Annual hourly energy simulation
- Results

(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)
Sustainable design with BIM

- **Green BIM** in sustainable infrastructure
  - Planning site location and analysis
  - Planning building design and analysis
    - The use of natural ventilation, natural lighting and shading effective measures
    - The use of solar energy
    - Rainwater recycling and waste recycling
    - The use of permeable ground & green materials
    - Focusing on ecological maintenance
    - Energy-efficiency and performance analysis

Sustainability consultant and BIM for integrated project delivery

(Source: https://www.macrodesignstudio.it/2017/02/14/the-potential-of-bim-as-a-sustainable-design-tool/?lang=en)
BIM supported analysis

- BIM can be used for:
  - Decision making
    - e.g. placement, orientation and massing of site/building (by evaluating overshadowing, solar access, prevailing wind using 3D visualization & energy analysis)
  - Building performance analysis
    - Fenestration orientation, heat loss/gain, daylight
  - Planning for renewable energy systems
    - e.g. shading & visual impact
  - Rating compliance (green building assessment)
Example of early sustainable design decisions

How could I optimize occupancy?

How much energy should my building use per year?

How can I utilize the surrounding land to reduce energy waste?

Which envelope material will reduce energy the most?

Could I power my building with photovoltaics and wind power?

To achieve net zero, should I go for a multi-story tower or a larger floorplate?

How much would adding insulation help reduce energy?

Should I change out my windows?

How sensitive is my portfolio to changes in weather?

How could I minimize embodied carbon and construction waste?

(Source: Autodesk)
# Building performance analysis & evaluation at design phase

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy modelling</strong></td>
<td>Reducing energy needs and analyzing renewable energy options that can contribute to low energy costs</td>
</tr>
<tr>
<td><strong>Building orientation</strong></td>
<td>Reduce energy costs</td>
</tr>
<tr>
<td><strong>Building massing</strong></td>
<td>Analyze building form and optimize building envelope</td>
</tr>
<tr>
<td><strong>Sustainable materials</strong></td>
<td>Reduce materials needs and use recycled materials</td>
</tr>
<tr>
<td><strong>Site and logistics management</strong></td>
<td>Reduce waste and carbon footprint</td>
</tr>
<tr>
<td><strong>Daylight &amp; lighting analysis</strong></td>
<td>Reduce energy costs &amp; improve indoor environment</td>
</tr>
<tr>
<td><strong>Wind &amp; ventilation analysis</strong></td>
<td>Optimize wind/ventilation effects to enhance air flow and air quality</td>
</tr>
<tr>
<td><strong>Water analysis</strong></td>
<td>Reduce water needs &amp; recycling in the building</td>
</tr>
<tr>
<td><strong>Economic analysis</strong></td>
<td>Forecast financial impacts</td>
</tr>
<tr>
<td><strong>Life cycle analysis</strong></td>
<td>Evaluate life cycle performance &amp; impacts</td>
</tr>
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(Videos: Conduct a LEED daylighting analysis directly from Revit (3:48) [https://youtu.be/L3x15tcRJCg](https://youtu.be/L3x15tcRJCg); A Quick Introduction To Insight & Revit’s Energy Modeling and Analysis Tools | Autodesk (21:44) [https://youtu.be/FNqS0K-Cr2Q](https://youtu.be/FNqS0K-Cr2Q))
Studies on sunlight & shadow, daylight and wind flow

(Source: Ms Ada FUNG, Hong Kong Housing Authority, https://www.hkis.org.hk/hkis/general/events/bim2013/bim-2013af.pdf)
Enhance cost control and environmental protection for “cut and fill”
Optimize lighting design for energy saving

Integration of neighborhood, building and surrounding lighting contribution to achieve optimum site lighting design.

Accurate simulation of 3D lighting level.

Development of more energy efficient lighting operation mode.

(Source: Ms Ada FUNG, Hong Kong Housing Authority, https://www.hkis.org.hk/hkis/general/events/bim2013/bim-2013af.pdf)
Wind & ventilation analysis in BIM

External air flow analysis

Internal air flow analysis

Wind Analysis in BIM https://sustainabilityworkshop.autodesk.com/buildings/wind-analysis-bim)
Life cycle assessment of buildings

Sustainable buildings lifecycle, technology, maturity

Capture & Model
- Generate BIM for new or existing buildings
  - 2D Drawings
  - Photogrammetry
  - Laser measurement
  - Laser scans
  - Conceptual Design

Simulate & Optimize
- Analyze energy and water use and compare scenarios
  - Energy Analysis
  - Data Availability
  - Energy Analysis
  - Onsite Renewables
  - Sensitivity
  - Optimization for Net Zero Energy

Procure & Build
- Resolve conflicts and reduce material waste during construction
  - Conflict detection
  - Sequencing & automation
  - Digital fabrication
  - Product/Materials selection
  - Product substitution analysis

Operate & Maintain
- Avoid energy ‘drift’ and adapt to new use scenarios
  - Facilities management
  - Asset management
  - Energy monitoring
  - Demand response
  - Performance Prediction

(Source: Autodesk)
Application of Sustainability in Buildings

Pre-Design
- Material Selection
- Building Program
- Project Budget
- Team Selection
- Partnering
- Project Schedule
- Laws, Codes & Standards
- Research
- Site Selection

On-Site
- Site Analysis & Assessment
- Site Development & Layout
- Watershed Management & Conservation
- Site Material & Equipment

Design
- Passive Solar Design
- Materials & Specification
- Indoor Air Quality

Construction
- Environmentally Conscious Construction
- Preservation of Features & Vegetation
- Waste Mgmt
- IAQ Issues
- Source Control Practices

O&M
- Maintenance Plans
- Indoor Quality
- Energy Efficiency
- Resource Efficiency
- Renovation
- Housekeeping & Custodial Practices
(O&M: operation and maintenance)
| Continuous analysis for environmental effects | Evaluate the environmental effects (e.g. air & noise pollution) & propose methods to lower them |
| Thorough design details | Minimize construction defects to reduce the ongoing operational costs and ensure a faster, safer construction |
| Material take-offs | Enable off-site fabrication using a co-ordinated model to eliminate over-ordering, reduce waste, allow off cut materials to be reused or recycled, and to achieve fewer deliveries to and less waste removal from site |
| Monitoring & recording building performance | Including water/wastewater, energy and carbon emission, to support better decisions for improvements |
| Updated alterations & changes to the building | Additions/adjustments made to building can be easily tracked and recorded |
| Seasonal commission and maintenance | Plan maintenance activities that can be synchronized minimizing cost and disruption of occupants |
| Access to sustainable information | Engage occupants and management with access to sustainability information and dashboards in their buildings |
Environ & economic aspects

• Waste reduction
  • Prefabrication
  • Material optimization
  • Buildability

• Embodied energy/carbon
  • Material selection
  • Life-cycle carbon/environmental impact
  • Whole life costs
Environ & economic aspects

- Parametric modelling & sustainable design
  - Form finding using BIM parametric modelling
  - Façade design
  - Analysis of aesthetics (w/ visualization)

- Rating compliance
  - Native BIM checking
  - Semi-native BIM checking
    - Export IFC or gbXML for analysis or visual check
  - Rule-based checking tools (apply custom rules)
Economical Aspects of Sustainability

A typical office building costs about three times its initial cost to operate and maintain over 30 years.

Carefully implemented sustainable design only costs 2% more to build but may pay back the original investment 10 times over.

Reduced energy consumption due to strategic green investments has a stronger effect on the Life Cycle Cost than the original investment.

„If the team members involved know what they are doing, you can go pretty far down the path of creating a green building without adding extra costs at all. „

Environmental Building News editor Nadav Malin

(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)
Economical Aspects of Sustainability

Life Cycle Analysis

Energy calculations and cost simulations can be used concurrently to ensure that energy-conservation and capital goals are met.

Whole Life Cost = LCC + Profit + non construction cost

Life Cycle Cost (LCC)
- Construction
- Operation
- Maintenance
- End of life

(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)
Economical Aspects of Sustainability

„Going ‘green’ pays off: sustainable design benefits people, the environment, and the bottom line. „

General Service Administration, U.S.

(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)
Analysis tools & workflow

• Integrate sustainable design tasks with BIM
  • 1. Separate software: can use file exchange with BIM or is integrated with a BIM server using a specific interface. It is easy to realise and use.
  • 2. The analysis function in BIM software: could be implemented by programming to BIM software.
  • 3. Integration with help of parametric formats: an intermediate solution that allows representing not only product information but also calculations used in the analysis.
Typical project phases and level of development

1. PRE-DESIGN
2. CONCEPT DESIGN
3. DESIGN DEVELOPMENT
4. FINAL DESIGN
5. CONSTRUCTION
6. BUILDING OPERATION

**MANAGEMENT OF PROJECT**

**DESIGN PROCESS**
- Pre-Design
- Concept Design
- Design Development
- Final Design

**LEVEL OF DEVELOPMENT**
- LOD 000
- LOD 100
- LOD 200
- LOD 300

**BUILDING LIFE CYCLE**
- Construction
- Building Operation

- LOD 400
- LOD 500

(Source: Project Phases & Level of Development [https://sustainabilityworkshop.autodesk.com/buildings/project-phases-level-development](https://sustainabilityworkshop.autodesk.com/buildings/project-phases-level-development))
Basic workflow of analysis at pre-design and conceptual design stages

(Source: Green BIM - Sustainability Through Integration https://www.slideshare.net/DimiF/green-bim-sustainability-through-integration-28248288)
Integrating BIM and energy analysis tools for sustainable building design

Analysis tools & workflow

• Analysis process using BIM and workflows
  • Knowing goals and metrics
  • Using tools for simulation & analysis
  • Design optimization decisions
• May need to use different models and different tools for different types of analysis, at different points of time in the process

(Source: BPA Software Workflows https://sustainabilityworkshop.autodesk.com/buildings/bpa-software-workflows)
Mapping analysis tools to design themes

**Strategy for sustainable design development:**

- Create an overview over possible tools
- Getting a technical understanding
- Mapping different tools possibilities and limitations
- Create understanding of interoperability
- Mapping tools to a design themes and processes

General process and workflow for sustainable building design

Inside:
- Modelling
- Simulation
- Visualization
- Analysis
- Transformation

Outside:
- Communication
- Collaboration
- Holistic analysis
- Design optimization

Further reading

• BIM as a Framework for Sustainable Design
  • http://www.susted.com/wordpress/content/bim-as-a-framework-for-sustainable-design_2012_03/

• Autodesk Sustainability Workshop
  • https://sustainabilityworkshop.autodesk.com/
  • Building Design
    https://sustainabilityworkshop.autodesk.com/building-design
  • BPA Software Workflows
    https://sustainabilityworkshop.autodesk.com/buildings/bpa-software-workflows

• Revit tools for BPA
  https://sustainabilityworkshop.autodesk.com/buildings/revit-tools-bpa