Innovation Strategies for the built environment in research, practice & teaching

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Innovation Strategies for the built environment in research, practice & teaching

- Introduction and motivation
- Case studies in different scales
- Conclusions
- Q&A
ARCHITECTURE
Qualitative
Conceptually driven

ENGINEERING
Quantitative
Science driven

Now
Next
New
Drivers

Productivity gap

Increase in output relative to employment (index, 1996 = 100)

(E C Harris ONS 2014)
Drivers

Surface temperatures

[Graph showing temperature anomalies from 1880 to 2010]
Source: NASA

Global population

[Graph showing world population in increments of 1 billion from 1800 to 2010]
Source: United Nations

Global energy demand (annual by region)

[Graph showing energy demand by region from 1980 to 2010]
Source: US Energy Information Administration 2014

0.1 Introduction
Drivers

Energy demand

- buildings largest consumers worldwide
- doubled between 1971 and 2010
- Under current policies global energy demand of buildings is projected to grow by an additional 30% by 2035 compared to 2010

Drivers

Performance rating systems

Impact of USGBC LEED & Building Research Establishment Environmental Assessment Method
Drivers

Reduction of UK [CO₂] Emissions by Sector

Source: UK Committee on Climate Change 2015.
DESIGN OPTIMISATION TOOL – VIRTUAL DESIGN STUDIO
SYRACUSE UNIVERSITY
US DEPARTMENT OF ENERGY

Architectural Design
Methodology focused
Interdisciplinary platform

Systems engineering
Following ADDAM structure
Qualitative and quantitative

Software scope
702,000 USD
US Department of Energy

Development
2010- ongoing

Team
P. Michael Pelken
Dr. Jianshun Zhang
Research Team

0.2 Teaching + Research related to Practice(s)
Virtual Design Studio

Development of a digital platform for integrated, fully coordinated and optimized designs of buildings, energy and environmental systems (BEES)

US Department of Energy funded project with an overall project value of $702,000 over 3 years
“Architect”

Teaching + Research related to Practice(s)

“Engineer”
0.2 Teaching + Research related to Practice(s)
# VDS ADDAM structure

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- **Site & Climate**
- **Form & Massing**
- **Internal Configuration**
- **External Enclosure**
- **Environmental Systems**
- **Energy Systems**
- **Water Systems**
- **Material Use and Embodied Energy System Interdependencies**

![Diagram of VDS ADDAM structure](image-url)
VDS ADDAM structure

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**INPUT**
- cultural / social / economical
- climactic / ecological
- program / functional / aesthetical

**OUTPUT**
- location / budget
- sources of labor & materials
- program req. / design concept performance criteria
- midlevel designs
- performance prediction (mid-conf. level)
- cost estimates more detailed specs
- final design
- performance prediction (high-conf. level)
- final cost estimate

**Design Stages**
- Strategic Briefing and Outline Proposals (B and C)
- Detailed Proposal (D)
- Final Proposals, Production Information and Tender Documentation (E, F, G, H)
- Mobilisation, Construction and Completion (J, K)
- After Practical Completion (L)

**0.2 Teaching + Research related to Practice(s)**
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**Diagram:**

- **Artificial Intelligence**
  - KBES (Knowledge-Based Expert System)
  - Matlab
  - trigger variable-based-simulation
  - decision making based on simulation results

- **Building Simulation**
  - Building Information
  - Store Simulation Result

- **Virtual Building**
  - Designer's Knowledge
  - Individual Consultants Mat. Developers

- **CACHE Database**
  - Industrial Standards vs. Design Customization

- **Tools:**
  - CHAMPS
  - Contam
  - E+
# VDS ADDAM structure

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### Design Stages Diagram

- **Architectural Design Team**
  - Master Planning
  - Architectural Design
  - Interior Architectural Design
  - Site and Landscaping Design

- **Project Management Team**
  - Client / Client Representative
  - Project Financial Management
  - Project Construction Management
  - Project Operations Management
  - All according to project scope and contract form

- **Systems Design Team**
  - Site and Civil Engineering Systems
  - Structural Systems
  - Active, passive and hybrid HVAC Systems
  - Water Systems
  - Energy Systems
  - Lighting Systems
  - Acoustics
  - Project specific additional scope

### Other Considerations
- Human interaction
- Supporting Artificial Intelligence
- Integration and coordination

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0.2 Teaching + Research related to Practice(s)
### Design Stages and Considerations

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### Material Use & Embodied Energy
- Source or origin of material
- Embodied energy
- Resistance to local climate condition
- VOC emissions

### Water Systems
- Water demand for service use
- Water demand for site
- Water demand for HVAC
- Water supply opportunities
- Water management system

### Energy Systems
- Energy for heating and cooling
- Energy for lighting
- Energy for service water heating
- Energy conservation and onsite generation
- Building energy modelling and analysis
- Energy management system

### Environmental Systems
- Heating and cooling needs and resources (active/passive/hybrid)
- Ventilation needs and resources (natural/mechanical/hybrid)
- Lighting needs and resources (daylight/artificial/hybrid lighting)
- Acoustics needs and resources

### Site & Climate
- Environmental assessment
- Sustainability issues
- Ideal site conditions
- Site context & orientation

### Form & Massing
- Preferences & precedent
- Climate adaptability
- Relation to surroundings
- Floor area ratio goals
- Building massing idea

### Internal Configuration
- Program distributions
- Circulation & spatial requirements
- Zoning

### External Enclosure
- Enclosure opportunities
- Solar control strategies (harvesting/storage/lighting)
- Renewable energy generation strategies
- Performance specifications
- Quality and quantity of openings
- Water run-off management
- Heat island effect reduction
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Whole life cycle assessment and post occupancy data processing

Validation of
- early design assumptions
- supporting simulation results
- whole building and environmental control system performance

Creation of VDS case study and reference building data base
Project set up and evaluation procedures
Project set up and evaluation procedures

Qualitative and quantitative project input
Project set up and evaluation procedures

Qualitative and quantitative project input

Discipline dependent representation of design evaluation
Project set up and evaluation procedures

Qualitative and quantitative project input

Discipline dependent representation of design evaluation

2D and 3D modeling and design viewer
“Syracuse University (SU) - Nanjing University (NJU) International Center in Sustainability” – Interdisciplinary VDS course work and research
“Virtual Design Studio”—Part 1: Interdisciplinary design processes

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Abstract

The Virtual Design Studio (VDS) is a software platform currently under development in support of an integrated, coordinated and optimized design of buildings and their energy and environmental systems. It is intended to assist collaborating architects, engineers and project management team members throughout the early phases of the detailed building design development. The platform helps to facilitate the workflow and the processing of information in combination with appropriate task-based performance simulation tools as better analyzed in Part 2 of this study (DOI: 10.1007/s11768-012-0131-1). The present paper summarizes how VDS relates to the building design process and its typical project stages, performance-based design considerations and respective performance optimization strategies. It outlines the methodology and scope for the organization, implementation and respective requirements for the VDS platform development based on the interdisciplinary design needs. Part 2 will present the methodology and software implementation of VDS.

Keywords

integrated design, design studio, building simulations, modeling, green building design

Article History

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1 Introduction

The Austrian philosopher Hans Blumenberg argued that the modern era of technologies, characterized by tools, instrumentality, and function, began in the late twentieth century to the age of systems, characterized by complex configurations, self-organization, and emergence. This shift induces the careful separation of design intention from means of construction codified in architectural conventions as well as the need for training, problem-solving conventions of engineering practice. The shift from tools to systems heralds the emergence of complex performative problems—active glass walls and self-powered buildings—that demand hybrid responses. Now practices are emerging from partnerships of architects, engineers, and others that blur disciplinary boundaries and advance new techniques in design and construction. […] Ecological, economic, and professional realities demand alternative models.

This quote from the ACSA (Association of Collegiate Schools of Architecture) 2011 Conference on “Performative practices: Architecture and engineering in the twenty-first century” (ACSA 2011) describes objectives that are very similar to ours for the development of an integrated Computer Simulation Environment for Performance-Based Design of very low energy and high IEQ (Indoor environmental quality) buildings. The development of an interdisciplinary design and simulation platform is hereby intended to address the above mentioned issues, the required flexibility and the application of a Holistic Systems Thinking.

Buildings designed and constructed using a performance-based energy and IEQ design process that optimizes the interaction between the building envelope and HVAC (heating, ventilation, and air conditioning) systems, among other design aspects, can save significant energy costs and provide better indoor climate and air quality. These buildings can be constructed for the same or nearly the
“Virtual Design Studio”—Part 2: Introduction to overall and software framework

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Abstract
The Virtual Design Studio (VDS) is a software platform for integrated, coordinated, and optimized design of buildings, buildings, and environmental systems. It is intended to assist engineers, architects, and other professionals in the early to detailed building design stages, as analyzed in Part 1 (DOI: 10.1007/s12273-013-0115-z). This paper presents an overview of the VDS design and development process, which includes system generation, design, and analysis software integration. A VDS user workflow is also illustrated with a simplified design example.

Keywords
Integrated design, digital tools, building simulation, modeling, green building design

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1 Introduction
Building system design is a multi-dimensional process involving multi-disciplinary design teams, multi-design factors, multi-performance objectives, and multi-objective optimization (Pelken et al. 2013). Designing a building is like solving a “magic cube” puzzle in which every step should be coordinated to reach the final solution efficiently. The design at a given stage needs to consider the primary parameters for the current stage, but also the parameters that are further considered in the more detailed subsequent design stages. These parameters include multiple factors such as Site & Climate, Form & Massing, Internal Configuration, External Envelope, Environmental System (HVAC), Energy Supply System, Water Supply System, Materials, and their Interdependences. How these factors impact on building performance needs to be analyzed in the design process. The design results should be updated from one stage to next with more detailed specifications towards achieving the design goals. Efficient and timely iterations are necessary among the different design factors in different design stages for trade-offs and optimization (Pelken et al. 2013).

Several software platforms have been developed to advance performance-based building design practices. DSST 8 (Pelken et al. 2008) and EnergyPlus (Zhang et al. 2006) are examples of the type of software tools that can be used to predict multi-zone pollutant transport. However, it does not differentiate the mode of different design stages and is not used to support the comparison of design performance versus actual measured performance.
MIXED USE DEVELOPMENT – PEACH BLOSSOM BAY, FANGCHENGANG
DEVELOPMENT COMPETITION AWARD WINNER, 2010

Design
4 mio. sqm in 4 weeks
2 time zones

Construction
Response to local climate
Hybrid building operation

2nd place Wining entry
International invited design competition

Development
4 mil sqm mixed use urban development

Team
P. Michael Pelken (USA)
Vasilena Vassilev (USA)
Minq Deng (China)
Climate Engineers (UTRC) Yi Jiang, Chang Xiaomin, Song Fangting; Tsinghua University Architectural Design and Research Institute

0.2 Teaching + Research related to Practice(s)
Teaching + Research related to Practice(s)
0.2 Teaching + Research related to Practice(s)
0.2 Teaching + Research related to Practice(s)
0.2 Teaching + Research related to Practice(s)
Plan 01

Wind Direction  | Avg. Wind Velocity (m/s)  | Height (m)
---|---|---
NNO | 4.66 | 1.5 m

Plan 02

Wind Direction  | Avg. Wind Velocity (m/s)  | Height (m)
---|---|---
NNO | 4.66 | 1.5 m

Introduction
Site Analysis
Planning Strategy
Urban Living
Architecture

Teaching + Research related to Practice(s)
Natural Ventilation
Natural Ventilation
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AIR CONTROL - INTEGRATED WIND TURBINES FOR ENVIRONMENTAL CONTROL AND ENERGY GENERATION

Project scope
Proof of concept

Development
NYSERDA and CoE funded

Construction
Reduced wind loads
Novel façade interfaces

Team
P.M. Pelken
Dr. Thong Dang
Research team
SU Technology Transfer Department
Air Control
Synergistic Integration of Flow Resistance Devices (VAWT’S) and Architectural Arrangements and Control Methodologies for a Novel Natural Ventilation Scheme to manage IAQ and other wind load specific requirements
Velocity Vectors

Allocated flow resistance device (Vertical Axis Wind Turbine or similar):

C2=0
C2=0.5 (Upper on)
C2=0.5 (Lower on)
C2=0.5 (Both on)

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Streamlines by pressure

Allocated flow resistance device (Vertical Axis Wind Turbine or similar): 

- C2=0
- C2=0.5 (Upper on)
- C2=0.5 (Lower on)
- C2=0.5 (Both on)

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Typical Plan

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Base condition - air distribution without flow resistance device

wind direction
Manipulated flow - air distribution with flow resistance device

VAWT

wind direction
Manipulated flow – impact of controlled air flow on interior d

VAWT

wind direction
Development strategies for interactive and hybrid HVAC control mechanisms

- Contaminant sensors (building interior)
- Pressure sensors (building exterior)

Model-based optimization

Resistance location

Window opening sizes
R&D opportunities:

- IAQ+ via enhanced natural ventilation
- responsive single layered façades
- Impact on conventional occupancy related room zone modeling
- Impact of reduced wind loads on building structure - material savings
- Interactive HVAC control and sensing
- Real Estate and FM Finance Models
P+ DEMONSTRATION BUILDING – COMPONENT TESTING
WUJIN, CHANGZHOU, CHINA
P+ DESIGN GROUP

Design
‘Living Lab’
Three programs for testing

Construction
Adoptable for building and component optimisation

<table>
<thead>
<tr>
<th>Building scope</th>
<th>Development</th>
<th>Team</th>
</tr>
</thead>
</table>
| 600 m² governmental project | Completed November 2015 | P+ Design Group
Institute of Architecture Design & Planning Co. Ltd., Nanjing University
Wujin Green Building Industry Development Zone |
GLOBAL NEW INVESTMENT IN RENEWABLE ENERGY BY REGION, 2014 ($BN)

- China 83.3
- United States 35.8
- ASOC (excl. China & India) 43.3
- Europe 57.5
- AMER (excl. US & Brazil), 12.4
- Middle East & Africa, 12.6
- India, 7.4
- Brazil, 7.6

Source: Bloomberg New Energy Finance - UNEP

Total
Three star projects
Two star projects
One star projects
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0.3 Teaching + Research related to Practice(s)
0.3 Teaching + Research related to Practice(s)
Teaching + Research related to Practice(s)

- A living lab - configuration changes
- Industry collaboration
- Academic research
- Testing of range of standards
- Component optimisation
- Building performance monitoring
Teaching + Research related to Practice(s)
Teaching + Research related to Practice(s)
Provide renewable energy and measure building performance
• Expo Park’s only weather station and used for regional climate monitoring
• Measuring IEQ and energy consumption in relation to outdoor climate
0.3 Teaching + Research related to Practice(s)
Interdisciplinary Graduate Level Research
SOLAR CHIMNEY MODEL VALIDATION & PERFORMANCE ENHANCEMENT

Guoqing He, Zhejiang University, guoqinghe@zju.edu.cn

OBJECTIVE
Validation of a plume model and a CFD model for predicting flow rates generated by a solar chimney under the solar radiation.

METHOD
Choose a sunny and windless day;
1. Measure flow rate in the solar chimney;
   Thermal anemometers; tracer gas; Atmospheric pressure;
2. Measure temperature in and outside the chimney;
   temperature of the walls and the glass, T of inlet and outlet;
3. Measure solar irradiation on the vertical surface, \( q_{\text{sol}} \);
4. Measure of the wind velocity at the inlet and the outlet;
5. Test of performance with variations:
   Change positions of the absorption plate or add extra absorption plate.

PhD Level Research
GREEN WALL – AIR PURIFICATION SYSTEM (2 WEEK SEMINAR)
SYRACUSE UNIVERSITY
WITH LC SMITH COLLEGE OF ENGINEERING

Design
New green wall typology
Interdisciplinary systems design

Construction
Living system
Modular assembly

Building scope
Based on the Wolverton System, a NASA spinoff technology

Development
Construction of Prototype

Team
P+ Studio
Prof. Dr. Jensen Zhang
Master’s level mechanical engineering students
Undergraduate + graduate architecture students
0.1 Introduction
Exhaust Fan
Ductwork
Aluminium Framing
Plywood
Foam Insulation
Irrigation System
Activated Carbon + Porous Shale Fill
Ductwork
Vacuum Formed Modules
Sensor Controlled Water Pump
Water Tank
Exposed Ductwork
Automated LED lighting
Planting
P
Green Wall Temperature Analysis

- Error layers
- Syracuse NY climate for outside layer

Air Circulation System
- CO₂

Base Fabric Soil Fabric Mesh Cover

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Green Wall Temperature Analysis

- Error layers
- Syracuse NY climate for outside layer

0.3 Teaching + Research related to Practice(s)
Air Flow Diagram

0.3 Teaching + Research related to Practice(s)
Design Build Research – Botanical Air Purification Wall System
Design Build Research – Botanical Air Purification Wall System
Design Build Research – Botanical Air Purification Wall System
Thank you for your attention!