

Optimal Conceptual Design of High-Rise Office Buildings

by

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Abstract

Design of a high-rise office building, like any engineering design, is a complex multidisciplinary process with the objective to discover, detail and construct a system to fulfill a given set of performance requirements. The success of this process is highly dependent upon the cooperation taking place between the members of the design team. Although present-day engineering computer technology allows for precise analysis and design of the different subsystems of a high-rise building, it does not readily provide insight for choosing among alternatives of these subsystems to arrive at the best overall design.

This research study presents a computer-based computational method for optimal cost-revenue conceptual design of high-rise office buildings. Specifically, a Multi-criteria Genetic Algorithm (MGA) is applied to conduct Pareto optimization that minimizes capital and operating costs and maximizes income revenue for a given building project, subject to design constraints imposed by building codes and fabrication requirements.

The conceptual design process involves the coordinated application of approximate analysis, design and optimization. To commence the design process, a population of different alternative designs are generated. Using approximate analysis and design based on pre-developed databases, the values of the conflicting cost-revenue objective criteria are established for each design. Then, a MGA is used to explore the design space and find improved designs having enhanced values of the objective criteria. The results, for a given building project, is a set of Pareto-optimal conceptual design that

define the 'trade-off' relationships between the three competing objective criteria to minimize capital cost, minimize operating cost and maximize income revenue. The corresponding three-dimensional criteria space is populated by feasible conceptual designs that are 'equal-rank optimal' in the sense that each design is not dominated for all three objective criteria by any other feasible design possible for the building. Life-cycle costing is introduced to investigate the profit potential of building design over time. The conceptual design of four example office buildings are conducted from a variety of viewpoints to illustrate the capability of the computational procedure to create comprehensive computer-generated colour graphic representations of optimal cost-revenue trade-off relationships for office buildings taking into account architectural, structural, mechanical and electrical systems. While this study focuses on office buildings and corresponding cost-revenue criteria, the proposed computer method for conceptual design is directly applicable to any type of artifact and related objective criteria.

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Tomyparents

Notation

a	direction of the length of the building
a_{max}	maximum length of the building
ABE	Angle of Building with East (degree)
$ACDT_{max}$	max Average Cold Day Temperature (C °)
$ACDT_{min}$	min Average Cold Day Temperature (C °)
$ADBL_a, ADBL_b$	Average Distance Between column Lines in a & b directions
$AHDT_{max}$	max Average Hot Day Temperature (C °)
$AHDT_{min}$	min Average Hot Day Temperature (C °)
AOT_{max}, AOT_{min}	Ave. max. & min Outside Temp. (C °)
AR	Aspect Ratio D_a/D_b
A_{req}	the required floor area of the building (m ²)
b	direction of the width of the building
b_{max}	maximum width of the building
BT	Bracing Type
$BWLP$	Basic Wind Load Pressure (kPa)
C_a, C_b	Core dimensions in a & b directions
$CCLF$	Concrete Cost Location Factor (ratio of local concrete cost to US national average concrete cost)
CDF	Core Dimension Factor: the ratio of a core dimension to the dimension of the building in the same direction
$CDRH$	Cold Day Relative Humidity (%)
$CDTR$	Cold Day Temperature Range (C °)
CFA	Column-Free Area factor
CFT	Concrete Floor Type
CLC	Cladding Color (greatly effects the HVAC system)
$CLCLF$	Cladding Cost Location Factor (ratio of local cladding cost to US national average cladding cost)
CPD_{min}	minimum Core to Perimeter Distance for the building
CSP	Clear Sky Percentage (ratio of clear sky hours to total hours in

	ayear)(%)
D_a, D_b	Building Dimensions in a & b directions(m)
$DCDD$	Direction of the Core Dimension to be Designed first(a or b)
DF	Depth of Floor(m)
DIT	Desired Inside Temperature($^{\circ}\text{C}$)
$ECLF$	Electrical Cost Location Factor(ratio of local electrical cost to US national average electrical cost)
E_LCLF	Elevator Cost Location Factor(ratio of local elevator cost to US national average elevator cost)
$FCLF$	Forming Cost Location Factor(ratio of local forming cost to US national average forming cost)
F_LCLF	Finishing Cost Location Factor(ratio of local finishing cost to US national average finishing cost)
FLC	Fixed Land Cost(\$)
h_{cle}	floor-to-ceiling clearance height
H	Height of the building(m)
H_{max}	maximum Height of the building
$HDRH$	Hot Day Relative Humidity(%)
HF	Height of Floor
IR	Inflation Rate(%)
IRH	Inside Relative Humidity(%)
ISA	Interior Surface Area of exterior walls
LA	Latitude Angle(degree)
LR_{max}, LR_{min}	max & min Lease Rates(\$/m ² Yr.)
$MCLF$	Mechanical Cost Location Factor(ratio of local mechanical cost to US national average mechanical cost)
MR	Mortgage Rate(%)
NCL_a, NCL_b	Number of Column Lines between the perimeter and core of the building in a & b directions
NE	total Number of Elevators
NF	Number of Floors

<i>NO PF</i>	Number of Occupants Per Floor
<i>NRF, NMF</i>	Number of Rentable and Mechanical Floors
<i>NRSC</i>	Number of Risers in a Stair Case for one floor
<i>NS_a, NS_b</i>	Number of Spans in <i>a</i> & <i>b</i> directions
<i>NSC, WSC</i>	Number and Width of Stair Cases
<i>NSE, NPE,</i>	Number of Service and Passenger Elevators
<i>NTS_a, NTS_b</i>	Number of perimeter Tube column Spans within spans <i>S_a</i> and <i>S_b</i>
<i>OILSC</i>	Overall Inside Length of Stair Case
<i>OIWSC</i>	Overall Inside Width of Stair Case
<i>RCLF</i>	Reinforcement Cost Location Factor (ratio of local reinforcement cost to US national average reinforcement cost)
<i>R_oCLF</i>	Roofing Cost Location Factor (ratio of local roofing cost to US national average roofing cost)
<i>S_a, S_b</i>	Span distance in <i>a</i> & <i>b</i> directions (m)
<i>SCLF</i>	Steel Cost Location Factor (ratio of local steel cost to US national average steel cost)
<i>SFT</i>	Steel Floor Type
<i>SR</i>	Slenderness Ratio for building
<i>ST</i>	Structural Type
<i>TCS_a, TCS_b</i>	Tube Column Spans in <i>a</i> & <i>b</i> directions
<i>TMAX_m</i>	MAX Temperature for sampled day <i>m</i> of each month (C °)
<i>T_{mh}</i>	hourly Temperature for sampled day <i>m</i> of each month (C °)
<i>TMIN_m</i>	MINT emperature for sampled day <i>m</i> of each month (C °)
<i>TNO</i>	Total Number of Occupants
<i>TR</i>	Tax Rate (%)
<i>UCEE, UCGE</i>	Unit Cost of Electrical and Gas Energy (\$/mwhr)
<i>ULC</i>	Unit Land Cost (\$/m ²)
<i>WAT</i>	exterior Wall Type (Cladding)
<i>WCLF</i>	Window Cost Location Factor (ratio of local window cost to US national average window cost)

<i>WIR</i>	WIndow Ratio(theratioofwindowareatothemaximum possiblewindowareaontheperimeterofabuilding)
<i>WIT</i>	WIndow Type

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