

# Computer-aided design in urban development and management—A software for integrated planning and design by optimization

B.K. Chakrabarty\*

*A-10 Qutab Enclave (Phase-I), Jeet Singh Marg, New Delhi-110016, India*

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## Abstract

Planning and Design in Urban Development, consuming large *Resources* entailing many variables giving numerous solutions with large variations in *resource-efficiency* indicators, is a *problem-solving process* (Mitchell WJ. Computer-aided architectural design. New York: Petrocelli/Charter; 1977) involving *search* through *numerous* potential solutions to select a particular solution that meets a specified criteria, making computer-use indispensable. Planners/Designers (e.g. engineers/architects/planners) *Commit* huge *Resources* (e.g. money, land, materials), in their *planning-design-decisions* (i.e. *planning* function, 1 of 5 *urban managerial* functions) forming part of *Integrated Urban Management* (Chakrabarty BK. Urban management: concepts, principles, techniques and education. Cities, vol. 18/5. Amsterdam: Elsevier Science; 2001), enjoining on them an *Ethical Responsibility/Accountability* to the *Society* to achieve *Productivity* and *Equity* in *Resources-Use* so committed for a *resource-efficient* housing/urban problem solution. *Operations Research (Optimization)* and *computer-aided design (CAD)*, are essential *Techniques* to improve *Productivity* (Koontz H, Weihrich H. Essentials of management. New York: McGraw-Hill Publishing Company; 1990; Koontz H, O'Donnel C. Management—a system and contingency analysis of managerial functions, New York: McGraw-Hill Publishing Company; 1976). Hence, it is vital that planners/designers apply (facilitated by modern computers) *CAD/Optimization* (even ancients applied *Optimization*) to *discharge their above Accountability to the Society*, for a *Resource-Efficient* and *Equitable* solution of housing/urban problems, in the context of rising population and dwindling *Resources*, particularly because we *live in a Finite Earth with Finite Resources and no rational decision is really complete without Optimization*.

CAD primarily depends on: (i) system software—supplied with the hardware, and (ii) application software—available commercially or to be developed in-house. A number of descriptive/*optimizing* urban development models are developed and published earlier (Chakrabarty BK. Models for the optimal design of housing development systems. Environment and Planning B 17(33); 1990; Chakrabarty BK. Optimization in residential land subdivisions. Journal of Urban Planning and Development, American Society of Civil Engineers 117(1); 1991; Chakrabarty BK. Optimal design of multifamily dwelling development systems. Building and Environment 31(1); 1996; Chakrabarty BK. Urban management and optimizing urban development models. Habitat International 22(4); 1998). These are being converted into an Application Software to help apply *Integrated CAD by Optimization* to improve *productivity* and *equity* in housing and urban operations. The paper outlines the Application Software: *HudCAD*, which covers all four components of *Integrated CAD* (Hsu T, Sinha DK. Computer-aided design: an integrated approach. St.Paul: West Publishing Company; 1992) i.e. (i) geometric modeling (ii) design analysis/*Design Optimization* (iii) drafting/drawing, and (iv) data management, storage and transfer; *rarely available in commercial CAD systems* built primarily to perform *geometric modeling/drafting*. Application of *HudCAD* is illustrated with example problems. Addition of “Computer-Aided Planning and Design by Optimization” as a *subject* of study in the courses of existing disciplines of engineering/architecture/planning, rather than developing optimization specialists unable to comprehend the systems to be optimized, is suggested. This would equip such urban professionals to apply CAD by Optimization in housing/urban operations to achieve a *Resource-Efficient* and *Equitable* solution to our mounting housing and urban problems.

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\*Tel.: +91 011 26520564.

E-mail address: [bibhutichakrabarty@yahoo.co.in](mailto:bibhutichakrabarty@yahoo.co.in).

## 1. Introduction

Urbanization is the most dominant phenomenon in all developing countries and is inevitable, since it is directly linked with their economic growth, indicated by the fact that urban population forms an overwhelming majority in all developed countries [1,2]. As per estimate, the world has crossed a demographic milestone i.e. for the first time in the history of humankind urban population is more than rural population [3]. Urban development entails huge consumption of *resources* (money, materials, land, energy and so on), which are always inadequate compared to the need. Hence, *productive* use of such *resources*, adopting an *Integrated Urban Management Approach*, is essential for a *Resource-Efficient* and *Equitable* solution to our mounting housing and urban problems. In this context, Planning and Design in Building/Housing/Urban Development, entailing many variables and giving numerous solutions with large variations in *resource-efficiency* indicators, needs to be viewed as a *problem-solving process* involving *searching* through *numerous* potential solutions to select a particular solution that meets a specified criteria or *goal*, making computer use indispensable.

Moreover, Urban PROFESSIONALS (e.g. building/civil engineers, architects, planners) *Commit* huge *Resources* (e.g. money, land, materials etc.) in their *Planning-Design-Decisions* (i.e. *planning* function, 1 of 5 *urban managerial functions*) in Urban Operations, forming part of *Integrated Urban Management* [4], making them *Ethically Responsible/ACCOUNTABLE* to the *SOCIETY/User Citizens* to achieve *PRODUCTIVITY* (output–input ratio) and *EQUITY* in the use of *Resources* so *committed* in their *plans/designs* to produce building/urban services. *Operations research (OR)* and *computer-aided design (CAD)*, are essential *Integrative Techniques* to improve *Productivity* i.e. *Efficiency* and *Effectiveness* [5,6]. Hence, it is vital that above Professionals apply such Techniques in planning and design and achieve *Optimization* to *discharge* their above *Responsibility/Accountability to the Society/People* for a *Resource-Efficient* and *Equitable* solution of our mounting housing and *urban problems*, in the context of *affordability* and *resource* constraints, and the conflicting interests/viewpoints/demands of *multiple-stakeholders* in the building/urban sector. Even the ancients applied *Optimization*, which is rarely applied in our modern building/housing/urban development operations creating many *inefficiencies* and *inequities* and consequent urban problems. Applying such Techniques/*Optimization* in all urban operations has become more *crucial* (also facilitated by modern computers), as: (i) *we live in a Finite Earth with Finite Resources*, (ii) in many countries, per capita *Resource* is reducing with increase in population (in India per capita land has reduced from 1.42 in 1901 to only 0.3 ha in 2001), (iii) *no rational*

*decision-making process is really complete without Optimization* [7], and (iv) there can be *large variations* in the *Resource-Efficiency Indicators* depending on the *Planning and Design Decisions* of Urban Professionals in the urban operations, creating a large scope for *Resource Optimization*.

The paper discusses Planning and Design as a problem-solving process and the useful role of computers in this process. It outlines the concept of OR and *Optimization* and the utility of CAD to apply such techniques to achieve *efficiency* and *equity* in the housing/urban operations. CAD primarily depends on: (i) system software—supplied with the hardware, and (ii) application software—available commercially or to be developed in-house. To promote application of CAD by *Optimization* in housing and urban development a number of descriptive and *optimizing* (nonlinear programming) models have been developed many of which are published elsewhere [8–11]. These are now being converted into an Application Software to help apply Integrated CAD by *Optimization* to improve *productivity* and *equity* in housing and urban operations. The paper presents an Application CAD Software named *Housing and Urban Development Computer-Aided Design (HudCAD)*, which combines all three elements i.e. *cost, design optimization and drafting*, solves the above *nonlinear programming models*, and converts *instantly* the *numerical solution* into a *graphic* output, with interactive inputs from the designers, who can obtain *optimal solution* in *numeric/graphic* form, even if not skilled in such techniques. Thus, *HudCAD* covers all four components of Integrated CAD [12] i.e. (i) geometric modeling (ii) design analysis/*Design Optimization* (iii) drafting/drawing, and (iv) data management, storage and transfer; *rarely available in commercial CAD systems* built primarily to perform *geometric modeling/drafting*. Application of *HudCAD* is illustrated with example problems.

*Optimization* (choosing optimal values of system variables) is the last of the three-step *rational decision-making* process [7]. In the other two steps i.e. knowledge/description of the system and finding a measure of system effectiveness, the professional knowledge of architects, engineers and planners would be of crucial importance. Hence, addition of “Computer-Aided Planning and Design by Optimization” as a *subject* of study in the professional courses in above existing disciplines, rather than developing optimization specialists unable to comprehend the systems to be optimized, is suggested. This would equip such urban professionals to apply CAD by *Optimization* in housing/urban operations and promote research to enlarge and refine such techniques for more effective application, and thus, help achieve a *Resource-Efficient* and *Equitable* solution of our mounting housing and urban problems.

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