when there is no obvious financial gain. In the absence of such consideration, the outcome is an increasing development of interest within construction management. As more organisations recognise the benefits of employing CAD systems, the overlap in the services which they offer to clients will continue to erode long standing professional barriers. This is likely to accelerate as technology and cost move within the reach of an increasing proportion of the construction industry.

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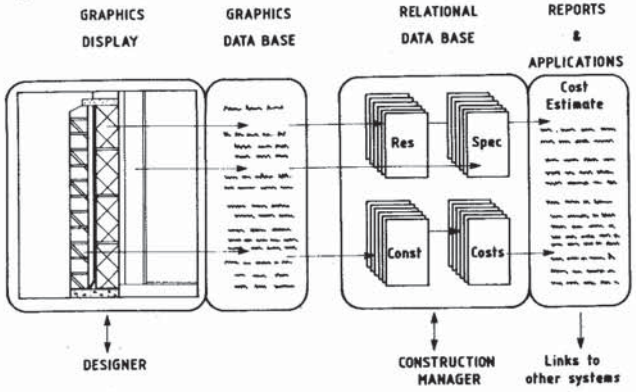

FIG. 1: SCHEME OF COMPUTER-AIDED DESIGN AND EVALUATION SYSTEM

Mathematical Modelling and Electronic Computing Machinery in Town Planning

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Urban Design, Computer-Aided Design, Program Pack, Mathematical Model, Information Provision.

ABSTRACT

The report deals with the main applications of mathematical methods and electronic computing machinery for the town planning needs with a view to: organize the information retrieval systems and data banks; undertake labour-intensive calculations; prepare the project documentation and model the design objects performance in order to evaluate the planning decisions. There follows the basic principles of the mathematical models used to solve the town planning problems including analysis of the land use and land-use zoning, analysis and evaluation of urban planning patterns, location of public service facilities, transportation planning, environmental quality evaluation, etc. The report contains information on the mathematical models implemented in the applied program packs, peculiarities of their use in conventional design, results and efficiency of their use. The concept is discussed of a technological line for the computer-aided development of the town master plan based on a wide use of mathematical modelling, computer-aided means to undertake the labour-intensive calculations and to prepare the project documentation. Also discussed are the possibilities and prospects of the computer-aided urban design.

Simulation mathématique et technique de calcul électronique utilisées lors de l'etudes sur l'urbanisme

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MOTS CLEFS

Etude d'urbanisme, Elaboration de projets à l'aide des ordinateurs, Paquet des programmes, Modèle mathématique, Alimentation en information.

SOMMAIRE

Le manuscrit traite des tendances principales de l'emploi des méthodes mathématiques et de la technique de calcul électronique lors de l'élaboration des projets d'urbanisme dans le but de l'organisation des systèmes de recherche de l'information et des banques de données, de l'exécution des calculs exigeant beaucoup de main d'oeuvre, de la préparation de la documentation de projets, ainsi que dans le but de la simulation du fonctionnement des élements étudiés pour évaluer des conceptions des solutions adoptées. On expose des principes des modèles mathématiques utilisés pour la solution des problèmes d'urbanisme notamment concernant l'analyse de l'affectation des sols, l'analyse de l'affectation des sols, l'analyse et l'évaluation des structures d'aménagement des villes, de transports, l'evaluation de l'environnement etc. Le manuscrit fait connaitre des modèles mathématiques réalisés en paquets des programmes appliqués pour l'ordinateur, des aspects particuliers de leur utilisation lors des études d'urbanisme traditionnelles, ainsi que des résultats et de l'efficacité de leur application. On decrit la conception de la chaine technologique de l'élaboration automatisée du projet du Plan directeur d'une ville s'appuyant sur une large utilisation de la simulation mathématique, des moyens de l'automatisation des calculs exigeant beaucoup de main d'oeuvre et ceux de la préparation de la documentation de projet. L'exposé initie aussi aux possibilités et aux perspectives dans le domaine de l'automatisation des processus d'élaboration des projets d'urbanisme.

Town planning is one of the principal elements in the implementation of the program of the USSR economic development and raising the living standard of the Soviet people. Management of urban development should be based on the comprehensive system approach to the solution of general and specific tasks with a wide use of mathematical modelling and computers.

Modern computing machinery is a powerful instrument that makes it possible to considerably intensify the design process, to facilitate and accelerate the labour of a planner and to considerably improve the quality of project decisions to be taken. Computers are used as a basis to develop and widely apply various systems such as the information retrieval systems that supply the necessary input data for the town planning needs; systems of computer-aided processing of data obtained as a result of various surveys and inventories; systems of computer-aided preparation of design and estimate documentation and graphic design materials.

Efficient operation of the above works can be illustrated by the examples drawn from the experience of large design institutes subordinated to the local Soviets of the People's Deputies in Moscow, Kharkov, Kiev, Leningrad, etc. They include data banks on the population housing stock, utility networks, etc. that have been formed and are continually supported and used in the above institutes. The Central Research and Design Institute for Town Planning developed a special system to process the data of comprehensive urban transportation and sociological surveys that was used to analyse the data of surveys conducted in the course of developing the comprehensive transportation schemes for more than 40 Soviet towns.

Of wide use are various program systems designed immediately for the architects. They include special languages to describe the architectural and construction images which make it possible to analyse the aesthetic perception of the project decisions on the electronic screens of computers. They help to obtain automatically and in real time the images of future built-up areas, buildings, their fragments and interiors. In the USSR development of the above trend in the computer-aided design is promoted by research carried out in the Moscow Architectural Institute, the Central Research and Design Institute of Experimental Housing, the Planning Board - Mosprojekt I and others.

The Central Research and Design Institute for Town Planning developed the methodology for computer-aided evaluation and restriction of heights of the proposed developments with a view to ensure the integral visual perception of the city silhouette. It was actively used in the design practice of Tallinn, Kostroma, Baku and other towns.

Of wide use are also programs for estimating the noise contours of town and air pollution from stationary and moving (urban transportation) sources as well as programs for evaluating water pollution, etc.

Computers play an important role in raising the labour productivity of planners, especially, when used to design the utility networks, namely to estimate the resistance of building constructions, to determine the operation of water supply and sewage systems and equipment, to determine the resources and materials needed; to organise the construction process; to prepare the estimate documentation.

Speaking of the computer-aided design in the first place we usually mean the introduction of the given computer-aided devices in the design process to facilitate and accelerate the labour of a planner. The computer-aided techniques can be quite easily operated by an average planner and do not require his deep knowledge in mathematics or special skills in operating the modern computers. So, their use in the everyday planners activity makes it possible to automatise from 10 to 20 per cent of their work in the field of architectural and construction design. However, the use of mathematical methods in urban design results not only and not so much in the acceleration of the design process and in rapid performance of a great number of calculations called the "routine" ones but rather in getting high-quality indices and project characteristics; making project decisions close to the optimal ones; raising the validity and accuracy of the arguments used as a basis for the final project decisions. The efficient use of mathematical modelling and computers in town planning promotes also scientific research of regularities in the performance of towns and their sub-systems with regard to different aspects: economic, social and technical ones.

Development and use of mathematical methods for urban design (in the USSR it includes regional and town projects, detailed plans of town districts and their development projects) is associated with the development and evaluation of planning decisions, including land-use zoning, allocation of facilities, utility networks as well as evaluation of the environmental quality, etc. As a rule, standard mathematical models are not sufficient for the given purpose, thus, special models are required that describe the prototype town planning situations.

The Central Research and Design Institute for Town Planning developed special functional models and applied program packs to solve the problems within the framework of the master plans of towns including the following aspects: land-use zoning, allocation of cultural and consumer service facilities and organisation of the urban transportation.

The task of the land-use zoning consists in finding an optimal alternative for the allocation of the given set of urban functions within the observed area, i.e. zoning of the urban area according to different land uses (for example, town centre, residential areas of different population density, various communal and industrial zones, etc.) with the area required for each of the above functions being known. Solution of the land-use problem assumes that both newly allocated (active) functions and already allocated (passive) ones that characterize and invariable actual land-use situation (for example, a basic plan of the existing developing town) are to be taken into account.

The criterion underlying the optimization problem solution reflects, firstly, links between the active functions and the site that are characterized by engineering/geological, physical/geographic and economic conditions; secondly, links between the active and passive functions and, thirdly, links between the active functions themselves. It is characterized by costs for the allocation of functions (allocation costs) and costs for providing links between them (communication costs). The value of communication costs is determined with a view to draw nearer functions having well-developed links (for example, labour relations between the residential areas and employment) or, on the contrary, to promote mutual disintegration of certain functions (for example, residential zones and noxious industries).

Mathematically the land-use problem is solved as a problem of quadratic programming with binary variables and transportation-type restrictions.

The program pack for allocating public service facilities is based on the performance model of the system "population-public attractors". In this case "public attractors" are understood not as specific service facilities but rather as a certain function or a set of service functions located in the given region or within the service centre, for example, convenience shops, cinemas, theatres, recreation zones, i.e. service facilities visited by the residents on their preference. The model estimates flows of visitors to each facility differentiating their trips to home-based-home, work-based and returning home ones. Dynamics of the system performance is represented by disaggregation of the whole operational cycle (daily, weekly, hourly) into separate stationary situations, for example, weekend, evening peak hours of a working day or a concrete hour of the 24-hour period.

Applied program pack implementing the model of the public service system performance may be used to solve the following two problems: I) to estimate the given allocation alternative. The results obtained are used to determine the visitors flows and

the quality of allocation (actual frequency of visits, time costs, etc.) for each public attractor; 2) to optimize the allocation of public attractors which makes it possible to determine their optimal capacity provided that the relative load on each facility is equal.

The most valuable practical experience has been gained in using mathematical modelling to design urban transportation systems. Applied program pack of the transportation models is a multi-purpose software approach used to determine loads on different elements of the transportation network (transportation modes and routes, the network sections and nodes); to evaluate the transportation service of the whole town and of its regions (travel time costs, trip length); to differentiate the loads according to their structure (for certain time periods of the transportation network operation, with regard to transit characteristics, etc.) as well as to determine the technical and economic indices of the transportation network operation. In the programs a generalised model has been implemented that includes three stages: determination and evaluation of links between regions or objects, modelling of O-D trips between the objects and modelling of the modal split within the transportation network. It should be noted that each of the above stages is supported by a pack program resulting in a great variety of the model approaches. The program pack makes it possible to "assemble" an estimated urban transportation model based on the information of various degree of detail and different levels of abstraction ranging from a simplified level assuming the possibility of direct links by "air" distance between the O-D objects (obstacles, for example water barriers or large areas that are not to be cut by transportation communications are considered, if necessary) to the level that represents an actual organisation of mass passenger transportation routes or traffic operation in the transportation nodes.

The success of mathematical models of any kind would depend on their information supply. It is especially true for the urban performance models considering a very complex object - a town and its sub-systems whose performance depends on the interaction of various factors including technical, economic, social and ecological ones.

In order to represent the cartographic data in the form appropriate for computers it should be coded by special devices. Figures on the economic base, population level, design standards required for the problems solution are supplied from special data banks and information systems that were mentioned above. Besides, social data is a very important element of the information supply which determine the population attitude to the town planning situation. This information is obtained in the course of mass public sociological surveys. The data of

the above surveys is also processed by computers.

The functional program packs discussed are actively used in the design practice. Thus, in 1981-1985 the program packs were used to develop projects of master plans of towns, comprehensive urban transportation schemes, technical and other projects in towns of Kharkov, Riga, Tbilisi, Donetsk-Makeevka, Vilnius, Dnepropetrovsk, Irkutsk, Omsk, etc. (totally more than 50 important projects for 43 towns and regions). The economic effect of their introduction owing to the reduction of design costs amounted to 120,000 roubles; project decisions made on the basis of results obtained by the programs provide for the annual reduction of construction and operational costs estimating at 116,000,000 roubles.

The task of using as much as possible mathematical modelling in the town planning implies development of the whole complex of models interrelated with each other and with the planners activity as a single "man-machine" system rather than construction of a global mathematical model of a town (which seems unrealistic). Therefore, the design process should be disaggregated into separate fragments using the hierarchical principle of gradual detalization of the projects. The following project sub-systems are identified according to their object and operational characteristics: land use, planning and allocation of urban objects, arrangement of the territory, utility networks, transportation.

Each project sub-system is subdivided into several operation blocks ranked according to their degree of detail so that each subsequent block is characterized by a greater degree of detail than the previous one. At a certain stage of the design process blocks of the same rank of different sub-systems are to be implemented in turn resulting in the end in the project with the degree of detail specific for the given stage and harmonious with regard to the sub-systems.

Currently the concept of a technological line for the urban master plan development is worked out in detail, which implies a wide use of mathematical models and computers to undertake labour-intensive calculations and to prepare the project documentation.