ON COMPUTER MODELLING AND UTILITY ASSESSMENT OF BUILDINGS AND PROJECTS

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ABSTRACT: The paper describes the methodology of computer modeling of the building process of projects with utility assessment and the main principles of the integrated cost estimation, project management and quality assurance microcomputer based system developed recently. This expert system is based on quick modeling of the building process by use of typical construction technology network diagrams, which can be prepared in advance. The typical network diagrams can be modified according to the spatial conditions of a certain building and to the amount of construction works and materials. For utility assessment a vector of 10 main aspects (criteria) was created with a common measure unit and certain level of importance each. A database of construction processes was created including the aspects for utility assessment. Thus, the model of the building process can be made about 50 times quicker than by current project management systems and it can be used for bidding, project planning and management and utility assessment.

Keywords: *Construction Technology, Building Process, Network Analysis, Model, Utility Assessment, Project Management*

1. INTRODUCTION

When projects are to be undertaken they have to be efficiently planned at the investor's (owner's), architect's and contractor's sides. In the planning and design stage of the project several specific problems must be solved and many points of view have to be taken into this decision process. A lot of these questions can be efficiently solved by creating of a computer model of the building process of the project. The model must be based on the construction technology and cost analysis and must reflect all technical, technological and economical features. One of the significant questions is the utility of the project, too.

The utility can be defined as the quality or condition of being useful; usefulness. It is a very general concept for the user to be able to evaluate the utility of a building or of a project on the base of this definition. Especially the architect and the investor should have a simple computer method to be able to assess the utility of the project he wants to undertake or design. The utility of the project is a very complex idea. It is a hard work to assess the utility - it is not possible to evaluate the utility only as one magnitude, as for different participants of the building process – the owner (final user), the architect and the contractor of the project the utility of the building or of the project means something very different. Different features of the utility can be defined from the point of view of the whole community. Therefore more aspects have to be taken into the method of the utility assessment and a vector of criteria of utility assessment must therefore be created, see e. g. [2]. Naturally, all aspects do not have the same importance, so they must be allotted their weights (importance). It would be very advantageous if all utility assessments aspects could have the same exact measure unit and if they could behave as certain resources, so that they could be calculated mathematically. Then they could be put into a project computer modeling system as resources linked to building constructions and in this way the utility of a whole building or of a project which consists of several building constructions could be evaluated. For modeling of the building or of a project the methodology of construction technology design, see [4], can be very efficiently used. Therefore a lately developed project preparation and management system which includes the database of building constructions with 50 resources each and a big set of typical network diagrams that enable very quick creation of the model of a building or of a project consisting of more facilities, see [3], can be then used for the calculation. With the help of the system the user has the possibility to simulate the proposed composition of constructions and construction processes in the project and the time and resource allocation flow of the building process on a microcomputer even if the topical relevant data about the project in the planning stage are poor. The more precisely the task is determined; the better results can be obtained from the model. The method for the utility assessment of building and projects designed by the author is based on this concept and is briefly described below.

2. UTILITY ASSESSMENT ASPECTS

During the design of the criteria for utility assessment of buildings and project three main areas for the evaluation were stated – the contractor, the investor (owner) and the community. About 15 aspects for all areas were identified and finally 10 main criteria were picked out for the definition of the utility assessment vector. The criteria of the utility assessment vector are as follows:

1 for the contractor:
- realization technology
- environmental impact during the building process
- energy intensity during the construction
- risk during the construction

2 for the investor (owner):
- lifetime and fire resistance
- quality
- operation energy intensity

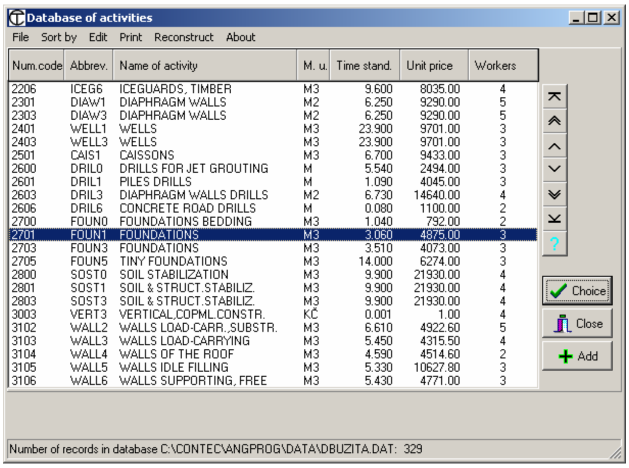
3 for the community:
- build-up of free area
- noise, traffic, operation emissions
- recycling of used materials

For all aspects a common measure unit was proposed – 1 finyar (fiňár in Czech), abbreviation 1 FIN. It is something like a special sort of currency and in this way all aspects can work as resources in the utility vector assessment calculation. The lesser the amount of finyars will be allotted for a certain criterion the better is the resulting assessment. The importance of all aspects was evaluated by a group of four experts. The aspects were mutually compared one to each other and at every comparison the value 1 was divided into two parts according to the higher of lower importance of the two compared aspects. If the importance of both compared aspects was equal both of them got the value 0.5. If one aspect was more significant than the other, it got the value from 0.51 to 1.0, the other got the value of the complement to 1. The actual values of weights (importance) of all criteria were then calculated as the average of values defined by mentioned four experts.

3. ON MEANS FOR MODELING THE PROJECT

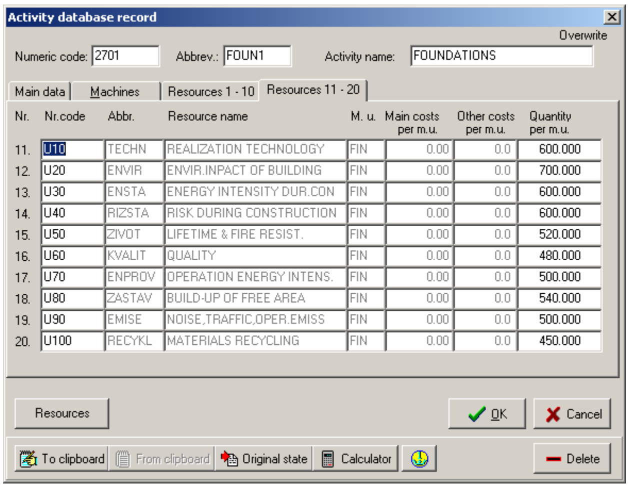
Three main means for quick modelling of a building that consists of constructions or of a building process which consists of construction processes were created. First, a database for the quick modelling of the building is available. This database consists of the main data about all constructions and construction processes at the technological structure of work gangs. It includes main facts about the time standard, productivity of labour, price of the product, number of workers, technological pause and other 20 economical and technological resources (material costs, wages, costs for machines, overheads, average profit, machines, materials, professions) and the utility aspects vector per measure unit of the construction. The values of the utility aspects are given in the interval <0 FIN/m. u.; 1000 FIN/m. u.>. The neutral value for each aspect is 500 FIN/m. u., the "good" values are lesser than 500 FIN/m. u., the "bad" values are greater than 500 FIN/m. u. The greater the value of FIN/m. u. of the aspect is the worse is the influence of the aspect on the utility. Nowadays, there are more than 500 building constructions and construction processes included in the database, see Fig. 1 and Fig. 2.

Second, a set of typical network diagrams of certain types of facilities and their way of erecting based upon the construction technology network diagram method, see [3] and [7], was created. The typical network diagram of a building process of a facility as a computer file contains the data about the sequence of the constructions and construction processes, and their linkage. The typical network diagrams can be easily modified according to the spatial structure of the actual building. The volume of production and costs and price of all constructions are included too. They are related to an adequate custom-made measure unit, usually m3 of build-in space or m2 of reconstructed area in case of a reconstruction. The typical construction technology network diagram can be modified according to the spatial structure of the building process by using the 3 main minimum working space indices.



Num.code	Abbrev.	Name of activity	M. u.	Time stand.	Unit price	Workers
2206	ICEG6	ICEGUARDS, TIMBER	M3	9.600	8035.00	4
2301	DIAW1	DIAPHRAGM WALLS	M2	6.250	9290.00	5
2303	DIAW3	DIAPHRAGM WALLS	M2	6.250	9290.00	5
2401	WELL1	WELLS	M3	23.900	9701.00	3
2403	WELL3	WELLS	M3	23.900	9701.00	3
2501	CAIS1	CAISSONS	M3	6.700	9433.00	3
2600	DRIL0	DRILLS FOR JET GROUTING	M	5.540	2494.00	3
2601	DRIL1	PILES DRILLS	M	1.090	4045.00	3
2603	DRIL3	DIAPHRAGM WALLS DRILLS	M2	6.730	14640.00	4
2606	DRIL6	CONCRETE ROAD DRILLS	M	0.080	1100.00	2
2700	FOUN0	FOUNDATIONS BEDDING	M3	1.040	792.00	2
2701	FOUN1	FOUNDATIONS	M3	3.060	4875.00	3
2703	FOUN3	FOUNDATIONS	M3	3.510	4073.00	3
2705	FOUN5	TINY FOUNDATIONS	M3	14.000	6274.00	3
2800	SOST0	SOIL STABILIZATION	M3	9.900	21930.00	4
2801	SOST1	SOIL & STRUCT.STABILIZ.	M3	9.900	21930.00	4
2803	SOST3	SOIL & STRUCT.STABILIZ.	M3	9.900	21930.00	4
3003	VERT3	VERTICAL,COPML.CONSTR.	KČ	0.001	1.00	4
3102	WALL2	WALLS LOAD-CARR.,SUBSTR.	M3	6.610	4922.60	5
3103	WALL3	WALLS LOAD-CARRYING	M3	5.450	4315.50	4
3104	WALL4	WALLS OF THE ROOF	M3	4.590	4514.60	2
3105	WALL5	WALLS IDLE FILLING	M3	5.330	10627.80	3
3106	WALL6	WALLS SUPPORTING, FREE	M3	5.430	4771.00	3

Fig. 1 Part of the listing of the database of construction processes.



Nr.	Nr.code	Abbr.	Resource name	M. u.	Main costs per m.u.	Other costs per m.u.	Quantity per m.u.
11.	U10	TECHN	REALIZATION TECHNOLOGY	FIN	0.00	0.0	600.000
12.	U20	ENVIR	ENVIR.INPACT OF BUILDING	FIN	0.00	0.0	700.000
13.	U30	ENSTA	ENERGY INTENSITY DUR.CON	FIN	0.00	0.0	600.000
14.	U40	RIZSTA	RISK DURING CONSTRUCTION	FIN	0.00	0.0	600.000
15.	U50	ZIVOT	LIFETIME & FIRE RESIST.	FIN	0.00	0.0	520.000
16.	U60	KVALIT	QUALITY	FIN	0.00	0.0	480.000
17.	U70	ENPROV	OPERATION ENERGY INTENS.	FIN	0.00	0.0	500.000
18.	U80	ZASTAV	BUILD-UP OF FREE AREA	FIN	0.00	0.0	540.000
19.	U90	EMISE	NOISE,TRAFFIC,OPER.EMISS	FIN	0.00	0.0	500.000
20.	U100	RECYKL	MATERIALS RECYCLING	FIN	0.00	0.0	450.000

Fig. 2. Chosen activity with utility assessment aspects.

Third, the CONTEC project preparation and management system, see [3], was adapted so that it is capable to calculate and evaluate the utility vector including the weighted values in a certain tabular form.

4. CREATING THE PROJECT MODEL AND CALCULATING THE UTILITY VECTOR

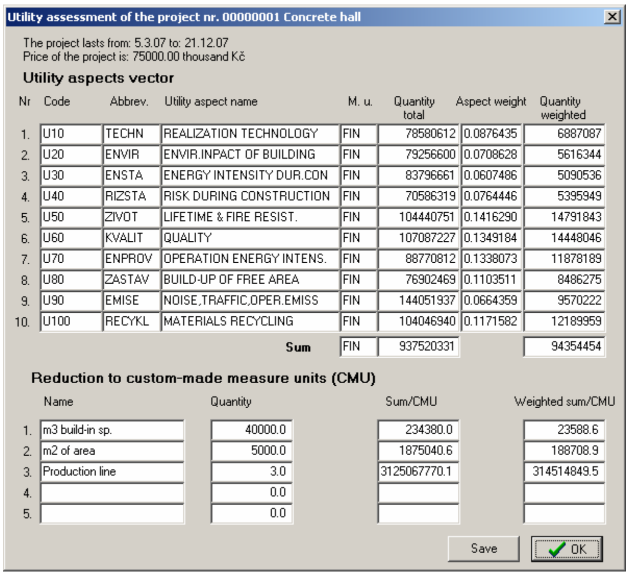
When the user wants to simulate the facility or the building process, in the first stage he defines up to 5 custom-made measure units for the building or for the project. Then he calls up the typical network diagram of the certain type of facility, modifies it by stating the actual main working space indices and the computer generates the first draw of the model of the composition of the building, including the time and cost analysis data which are transferred from the database of constructions. Thus, the user can get the first model much quicker than by the use of classical project management systems that require creating the network diagram by adding relevant activities one after another and stating their duration, resources and links. The created model has to be defined with more precision according to the facts known about the building. It is known that 80 % of the price and costs is influenced by 25 – 30 % of activities only. Volumes of production of these significant processes have to be stated according to the construction design, prices of the production, labour consumption and resources needed are calculated automatically according to the database of activities. If the exact bill of quantities is available its values can be automatically transferred into the model. After the calculation of the network diagram the user gets the early and late terms of starts and finishes of all activities. By the change of number of workers in the gangs or by changing the tension index of time standards the duration of activities and thus the whole network diagram can be modified. Activities of all sorts (not only those from the database) can be included into the network. After making these models for all buildings that are included in the project it is possible to make a network diagram of the whole project by connecting the partial networks and linking them together with flow links in case of continuous work of specialized work gangs in linked buildings.

Thus, it is not necessary to create the network diagram individually from the very beginning for every project. The expert system enables to build up the model of the building process of the project very quickly from prefabricated sections, typical network diagrams of different facilities, and to define it with more precision easily according to the facts gained from the investor's task. It can be easily updated in case of a change of different conditions. The network can be automatically recalculated from the point of view of keeping the deadline of the project required. The system then selects activities that have to be shortened by adding a certain number of workers or by increasing the intensity of work, while keeping technological rules and all links of the network. The system enables to print the calculated network diagram in different forms (technological standards, bar chart, line-of-balance graph, resource allocation graphs of price, costs and cash flow, labour consumption, need of work force etc.), in Czech, Slovak, English, Italian or Russian. Even in the very first stage of the plan it is possible to create the quality assurance checklist, see [1], the environmental plan, see [5], [8], and the safety-at-work plan, see [6]. The particular network diagram can be then aggregated into the higher information level of technological stages, steps of completion, to the level of facilities and others.

All documents that are gained on the base of the construction technology network diagram can be easily updated according to the actual completion of construction processes on site at a certain term. If there is a delay, the system suggests what measures are to be done to be able to keep the final deadline of the project. At the same time it keeps the technological rules of the building process. This can be visualized in the comparative bar chart, where the updated version of the building process drawn in thicker lines is compared in one document with the planned flow of the process.

According to the recalculated network diagram the line-of-balance graph (time-space graph) can be automatically drawn on the plotter.

After creating the model of the project the user can transfer the data about the utility aspects for all activities from the database mentioned above. The system then calculates the whole utility vector in a table form, see Fig. 3.



Nr	Code	Abbrev.	Utility aspect name	M. u.	Quantity total	Aspect weight	Quantity weighted
1.	U10	TECHN	REALIZATION TECHNOLOGY	FIN	78580612	0.0876435	6887087
2.	U20	ENVIR	ENVIR.INPACT OF BUILDING	FIN	79256600	0.0708628	5616344
3.	U30	ENSTA	ENERGY INTENSITY DUR.CON	FIN	83796661	0.0607486	5090536
4.	U40	RIZSTA	RISK DURING CONSTRUCTION	FIN	70586319	0.0764446	5395949
5.	U50	ZIVOT	LIFETIME & FIRE RESIST.	FIN	104440751	0.1416290	14791843
6.	U60	KVALIT	QUALITY	FIN	107087227	0.1349184	14448046
7.	U70	ENPROV	OPERATION ENERGY INTENS.	FIN	88770812	0.1338073	11878189
8.	U80	ZASTAV	BUILD-UP OF FREE AREA	FIN	76902469	0.1103511	8486275
9.	U90	EMISE	NOISE,TRAFFIC,OPER.EMISS	FIN	144051937	0.0664359	9570222
10.	U100	RECYKL	MATERIALS RECYCLING	FIN	104046940	0.1171582	12189959
			Sum	FIN	937520331		94354454

	Name	Quantity	Sum/CMU	Weighted sum/CMU
1.	m3 build-in sp.	40000.0	234380.0	23588.6
2.	m2 of area	5000.0	1875040.6	188708.9
3.	Production line	3.0	3125067770.1	314514849.5
4.		0.0		
5.		0.0		

Fig. 3. Calculation of the utility assessment.

All documents that are gained on the base of the construction technology network diagram can be easily edited and updated according to the actual compositions of constructions. The utility assessment method is completely free for the user. He can define his own utility assessment vector composed of his own aspects, he can identify his own values of weights (importance) of these aspects, he can even design his own database of constructions with allotting of the amount of FIN to every utility aspect in every building construction that is included in the database. Nowadays, there are 4 types of these databases available – the database for housing and structural engineering, the database for industrial buildings, the database for engineering structures (bridges, roads and infrastructure) and the database for hydraulic structures.

5. EXAMPLES OF USE

The main documents of the construction technology and cost analysis created in the mentioned way can contain the model of the building process of the project that includes all necessary data for the building process control and management, resource allocation balancing and utility assessment. The described way of preparation and management was used in some cases of reconstruction of historical buildings and in a large number of significant new projects.

A very interesting example of use of the system for modeling and cost and utility assessment of the reconstruction process of a historical building is the Toscano Palace near the Prague Castle, see Fig. 4. This renaissance palace belongs to the Czech Ministry of Foreign Affairs. The main purpose of reconstruction was to modernize especially the internal equipment of the building while conserving significant architectural and historical details, such as portals, towers, façade and the courtyard. In this case a lot of old frescos were discovered in the flow of the reconstruction which had to be renewed and the building process was stopped for 8 weeks. In that case the model of the reconstruction process had to be regularly updated (once a month approximately.). The main significance of the network model was in the capability of respecting of delays caused by these discoveries or due to other changes and to calculate measures to be done to keep the final deadline of the project. The resulting delay was only 3 weeks compared with the original schedule.

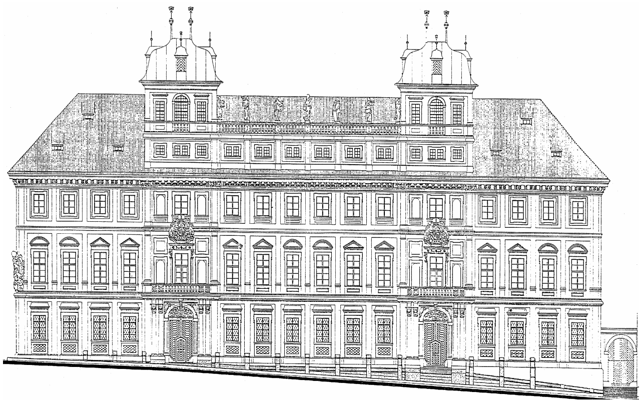


Fig. 4. Toscano Palace in Prague - western façade.

As an example of new significant projects it is worth noting the 20 storey block of flats U Sluncové in Prague, see Fig. 5. It was being built in one of the smallest building sites from the point of view of the area and it was finished in 2009. The system was used for creating of the particular time plan, utility assessment and quality assurance checklist at the start of the project for both the developer and the contractor.

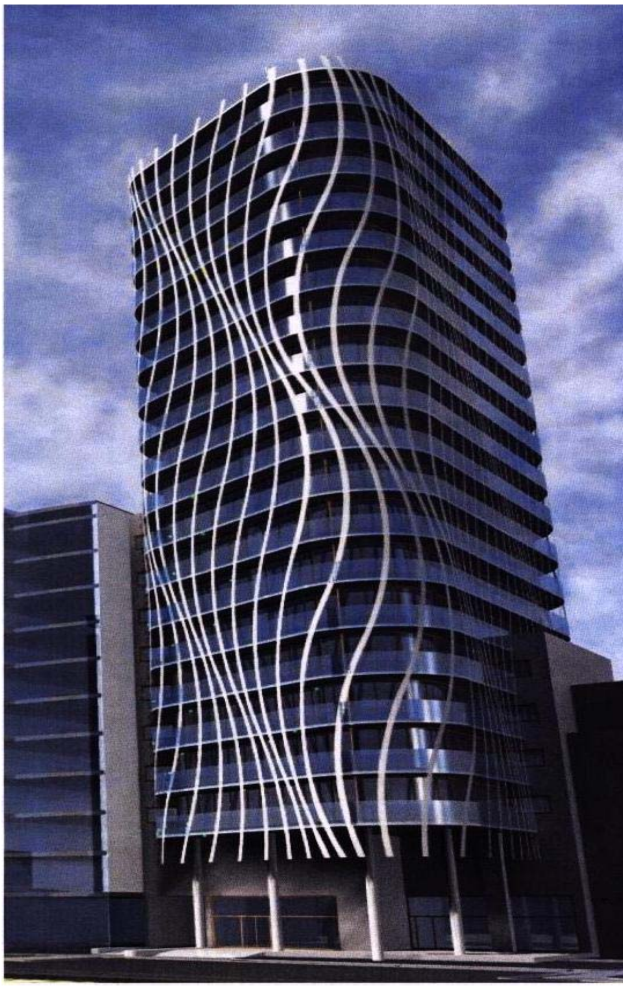


Fig. 5. Block of flats U Sluncové in Prague

6 CONCLUSIONS

This paper briefly describes a new design of the methodology of the utility assessment of buildings and projects. It is based on a vector of 10 main aspects (criteria) for utility assessment which was designed with a same measure unit. The aspects were given a certain level of importance each. A database of construction processes was created including the aspects for the utility assessment. On the base of the methodology of the construction technology design a method for modelling of realization of building and projects based on the construction technology network diagram with utility assessment was created and a computer system for this purpose was developed. This system is capable of a quick modelling of a building of a project that is composed from constructions by means of typical construction technology network diagrams. It enables to calculate and tabularly illustrate the resulting utility vector and its sum with regard to the importance of every utility aspect. The methodology is completely free for the user who can define his own values of every utility aspect, even the aspects themselves.

The main documents of the construction technology design created by the help of the expert system can contain the model of the building process of the project that includes all necessary data for the building or reconstruction process control and management. The system enables to create the building process model with appropriate cost assessment and time-cost analysis about 50 times quicker than current project management systems. It is possible to use the documents as a part of a feasibility study, bid, construction technology design and operative plan for the project management of the erection or reconstruction process itself. This model can be updated according to the bill of quantities or cost estimation. Afterwards the quality assurance checklist, the environmental plan and the safety-at-work plan can be automatically created. All documents can be easily updated according to the actual completion on site at a certain term. If there is a delay, the system suggests what measures are to be done in the future to be able to keep the final deadline of the project. All documents can be automatically translated to Czech, Slovak, English, Italian and Russian.

The designed methodology of the utility assessment and modelling of the building process of facilities and projects can be used especially in the phase of planning the projects by owners, designers and architects for utility assessment and much more – for feasibility studies, planning, obtaining bank loans to finance the projects and last but not least in project management itself.

The described system can be used on IBM PC compatible computers under Windows 9x, ME, NT, 2000, XP, Vista and Windows 7 operational systems.

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