Determination of engineering cost and time of construction with simulation technique

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Abstract: Traditional methods in determining engineering cost and time of construction are both complicated and clumsy and the result of which is wanting in convincingness. The determination of cost and time of construction for new techniques and new technology in construction works makes cost engineers more perplexed and at a loss. Along with the functions of computers becoming increasingly powerful, engineering design has been changed into simulation on the computer. Since construction is the means of materializing the design scheme, two vital indexes of engineering cost and construction time can no doubt also be obtained through the method of virtual reality and computer simulation. This article suggests that the method of establishing a model with electronic maps and of using the quantity of work to check the model be employed to attain virtual realities. Afterwards, through four levels of simulation and according to the capacity of labor and constructional plant, with the standards of quality, safety and environment as the objective, and with material characteristics, construction technology and construction methods as the basis, the operator will fulfill the construction task via computer simulation dispatch of all the resources, so that will be simulated the engineering cost under a special time of construction and the time of construction with an optimized engineering cost. This method, in case of being popularized in application, will become a revolutionary method in determining engineering cost and time of construction, of which the most outstanding feature is that it can determine engineering cost and time of construction in a simulated construction scene and through the construction process as if it were true. Thus, cost engineers are provided with more effective means to ascertain engineering cost and time of construction, which is where it is worth reference in this paper. The method proposed herein has not yet been exploited on a large scale in the practice of construction, still subject to further development and study. The same method when mature will help decision makers and cost engineers of engineering projects get rid of the suffocating document reading and preparation, turning heavy labor into light and merry games.

Key Words: Virtual scene; simulation; engineering cost; time of construction

0 Introduction

Broadly speaking, engineering design itself is to make analog calculations of the force on all positions of building products to ensure the safety, economic and applicable means and methods of the same. With buildings employing new materials, new techniques and new equipment in particular, consideration has also to be given in the design to the operability and the realizability of the analog construction means in the construction process. Since CAD is used for a great number of design links,

engineering design has been simply changed to simulation on the computer.

Construction being the realization means of design schemes**,** can computer simulation be used for the implementation process thereof ? The answer is in the positive. Along with the increasingly development of the computer, its functions have become more and more powerful. Rich experience has been accumulated from the extensive application of the computer analog technique in the fields of wars, aerospace, nuclear energy power generation, thermal power generation, petrochemical industry, metallurgy, light industry, etc. Then the virtual reality (VR) and emulation of engineering construction by computers has become barrier free both in terms of equipment and techniques. We hereby present the concept of using the virtual reality emulation technique to simulate engineering construction in a bid to materialize the control over engineering cost and time of construction.

1 Concept of construction simulation

Friends good at computers all have played the two strategic games of the *Age of Empires* and the *Red Alert.* The characteristics of the games of this kind are that the computer, based on the set program, will establish the game scenes and automatically distribute to each of the game players a certain amount of resources necessary for the warfare such as mineral products, food and timber. The players through the effective use of these resources will on the one hand develop the social civilization on his part to set up his own military power, and on the other hand conquer the enemy. The engineering construction in reality is in fact to complete the construction works through the construction management personnel exploiting labour, equipment and materials on a specially set scene.

The likeliness of the two is that the game player and the construction management personnel can both through reasonable mobilization of labour, equipment and materials reach up to the optimum configuration of resources so as to make the player speed up the development process of the game and rapidly develop and strengthen his own social and military power to finally fulfill his aim of defeating his enemy; or to make the constructor fulfill as quickly as possible his construction task and achieve the maximum economic benefits with the minimum input of resources. Whereas the difference between the two is that the resources obtained by the player at the initial stage is limited whilst the resources in the realistic construction work which can be manipulated by the constructor in the preliminary stage is free from any restriction.

Therefore, the simulated construction scenes, the first step in simulation construction is the same in a certain sense as the set game scenes except that in practical engineering construction, the resource input in unit scene is always greatest. The quicker the completion of a project, the more will be the cost spent on mobilizing these resources. In the meantime, restricted by the construction scenes and the characteristics of the project proper, the tighter the construction time schedule, the

more measures will be taken to ensure the engineering quality and construction safety and the more input of resources. Hence, the greater the cost resulting from the simulation construction by the computer, the poorer in certain the economic benefits. In other words, there is an economic crucial point between construction time and resource input and this point can be simulated by the computer, reflecting the engineering cost under a reasonable time of construction.

2 Simulation of construction environment

Simulation and analog technique refers to the virtual technique of mechanical equipment (instruments), models and computers, which is a comprehensive technique employing the site and environmental layout to simulate the real working program, working environment, technical index and requirement of action so as to carry out scientific research, industrial design, analog production, teaching exercises, checking & evaluation, etc. The user, through the natural interaction with the computer, will fully indulge himself in the virtual environment built by the computer. In case engineering construction and construction method are required to be computer simulated, the analog environment of engineering construction shall be first of all established. The virtual construction environment so imagined should be composed of three parts of software system, database system and hardware system. The software system mainly consists of the construction environmental modal establishment software, scenic texture generating and processing software, stereopicture generating software, observation and operation control software, analysis & application management information system software, etc. The database system mainly comprises construction map database, three-dimensional modal database, plant & equipment database, environmental texture image database, application subject database, etc. and the hardware system mainly embraces computers, acoustic image processing system, perception system(display equipment, stereovision device and ergonomic device), etc.

The engineering environment simulation describes the construction environment by making use of the above systems. The construction environment should be comprised of construction geographical environment, climatic environment, etc. of which the topographic environment is the physical backing for other environments and forms the basis whereupon to effect the spatial positioning and load construction information of various sorts whilst the climatic environment in turn has great impacts on construction activities. The realization of computer construction environment simulation first of all needs digitalizing of construction environment, which is then followed by the second time modeling of the construction environment, i.e. the construction environmental model is to be processed into a model fitting in with the application of construction simulation. The construction environmental model going through the second time model processing can be used for the computer to make the construction simulation. To ensure the construction simulation results accurate and reliable, the construction environmental model is asked to be of considerably high

accuracy, which needs testing on the model through analog tests. Construction environmental database is used for the computer to ‘recognize’ the construction environment and the process of turning the basic construction environmental data into the construction environmental model which can be recognized by the computer might be called “construction modeling” . The simulated construction environment model can demonstrate the construction environment via such main factors as visual simulation and acoustic effect. We can have a perception of the construction environment by way of a certain operating interface, e.g. the topography and surface features expressed by stereo, three –dimensional or two dimensional graphics and images can be seen from visual sense, the sound of wind blowing and raining and machine roaring can be heard through hearing whilst the man-construction environment exchange can be realized through feeling and the operation of man-machine interactive equipment.

As regards engineering construction projects involving railway, highway, municipal engineering, hydrology, hydroelectricity and buildings and structures, the computer simulation model of construction environment can be established through the following methods:

Pending the start of survey for an engineering project, 1:50000 and 1:10000 maps can be collected for use in the survey field. Besides the geologic maps, traffic maps and administrative maps of the said region can also be acquired. All these maps can be scanned by the scanner into the computer. Afterward, combined with the topographic map data obtained from the field survey and the roadway geometric data, maps of different scale and kind will be fitted and superimposed to form maps containing all kind of information. And these digitized maps serving as a basic model will be stored in the data base of construction maps. Along with the improvement of survey means, new techniques such as aerial survey and GPS plotting have been extensively used and the collection of digital maps has become simple and easy, creating much better conditions for the establishment of construction geographical environmental model. The digital maps collected can directly stored into the construction map data to serve as the basic model of construction geographical environment yet to be established. Then, the said maps will be stereoscopied and digitized to form the construction geographic environment model. During and after the survey of a project, are obtained the field surveyed data of the proposed line (structural) plans & profiles and geologic columns, and the calculated data of the line and structural plans, profiles and cross sections after the design of the project. All these data are placed in the construction geographic environmental model, which will be established for the second time to generate the visual graphs before and after construction and the geometric stereogram for construction yet to start. After the establishment of the static construction geographic environmental model, due to the enormous impacts of the meteorological environment on engineering construction, the meteorological factors such as replacement of the four seasons, concentrated rainy period and rainfall, number of snowy days and snowfall, mean temperature of the four seasons and the ultimate

temperature of the year will be in the mode of probability dynamically combined with the construction geographic environmental model, shaping a complete construction environment analog model. To better implement the computer construction simulation, the supply points of construction materials, the conditions of the road the traffic of materials will pass on and the factors of borrow pits and spoil banks will be all indicated in the construction environmental model.

After the construction environment simulation model is completed in establishment, the accuracy will be tested of the modal, and the topography and surface features will be tested to see whether they are in conformity with the actual. The construction environment simulation model is put into operation and observation will be made of the meteorological data to see whether they are close to the statistical data. The simulated bill of quantities are tested to see whether they are identical with the calculated figures. And whether the material supply plan through optimized analog calculation is as expected. Through testing, if the model is thought to be accurate and reliable, it can be used to simulate construction as if the simulation were made in the naturally virtual reality true to life. The engineering cost and the shaping process of construction period are thus determined through the visual interface and the feeling of being personally on the scene.

3 Determination of engineering cost and construction period with construction simulation

As is known to all that engineering cost is attained from the transfer of the consumption value of labour and substance (materials and machinery) involved in the project. Factors affecting the consumption of labour and substance are extremely complicated, and different construction technologies, different material supplies, different construction sequences and even the construction features and customs & habits of the construction unit all can make a great impact on the engineering cost and simultaneously these factors also determine the construction period. Taking a panoramic view of the various methods of determining the engineering cost and construction duration at present stage, these differences have been overlooked to a great extent. When the computer construction simulation is adopted however, the operator by having the above factors closely combined, can well indicate the characteristics of the project and the individual character of the construction unit. Referring to new techniques and technologies with high technical content, the process of visual operation can be realized with the calculation of engineering cost and the determination of construction period fulfilled through the computer dynamic simulation.

Construction simulation can be divided into 4 levels: Level 1 is of construction technology simulation which is mainly set in the construction environment simulation model. According to the classification of item projects and characteristics of topography, surface features, geology and climate of the engineering project, a couple

of schemes of mechanical equipment allocation and the classification of item projects are repeatedly demonstrated to achieve the optimum configuration of the model and the number of machines required by each of the item projects on the premise of meeting the limiting conditions, i.e. realizing the maximum thrift economically. Level 2 is of construction sequence simulation, which mainly licks the problem of construction sequences between different item projects so as to meet the limits of overall resources (labor and equipment) and non-violation of the technological sequence and simultaneously obtain the rational construction progress. Level 3 is the issue of material supply, which based on the consumption of labour and matter simulated on the two levels above, according to several factors of the price of material supplies & transport and the material supply capacity provided by the construction environment simulation model, adopts the mathematical programmimg model and reasonably makes the choice of the supply plan with a view to reaching the objective of maximum economy on condition that the limiting conditions are met of various sorts. The three levels stated above are reciprocal conditions and limits, which can both simulate the construction duration at the lowest engineering cost and the engineering cost in a particular construction period. Level 4 is of the display and playback of the analog results, whose main task is to have the simulated results through the display and acoustic equipment dynamically broadcasted with three dimensional cartoons and sound, making one feel personally on the scene, of which the specific realization method is: The panorama of the engineering construction at any time is stored in the graphic database with the connection established to each of the attributive data it corresponds to so that when the cartoons are displayed, the shape data and the corresponding attributive info in the graphic database read in the time sequence continuously update the evaluation of the plotting and attributive variables and at the same time refresh the display on the screen constantly, thus materializing the dynamic display of the three dimensional pictures and the corresponding information of the construction process of the integral project.

Through the above-stated simulation process, the "*analog clock*" can be used to record the working time of all the construction constituents and the construction sequence and time consumption of each of the part and item projects so as to further determine the engineering cost of each of the part and item projects and finalize the total engineering cost.

4 Simulation concept and process expounded by example

The simulation concept and process is now explained by the example of earth/rock work construction.

There are three problems need solving in the design of earth/rock work construction organization, viz. planning and control of earth/ rock storage yard; planning of transport road and organization and management of transport machinery; and organization and coordination of and between all the operational links in course of

earth/rock fill, and the drawing up and implementation of the construction time schedule. Based on the three major problems described above, earth/rock optimized cut-fill transition simulation model, construction transport simulation model and earth/rock fill process simulation model can separately established, and in accordance with the constraint relationship between the three, is integrated a complete earth/rock work construction simulation system. In the course of simulation realization, the complicated mathematical models will be extensively used of the linear programming, probability theory, queuing theory and storage theory.

Thinking in establishing the earth /rock optimized cut-fill transition simulation model: According to the internal and external influencing factors, the construction period of earth/rock work construction is divided into several time intervals within each of which the sources of supply and being supplied are determined. Pursuant to the initial scheme of the construction organization design, linear programming model is first established for each of the time intervals. Then a comprehensive numbering is made to the material yard of all of the time intervals of the construction period and combined with the practical requirements of construction, is finally formed the overall earth/rock optimized cut-fill transition mathematical model, of which the objective is to achieve the most economic cut-fill transition cost with the restraint conditions being: maximum supply volume; maximum supply volume acceptable, and the balance of supplies delivered and discharged.

The thinking of establishing the simulation model of earth/rock work operation sub-system is: A large scale of earth/rock work construction process is separated into several zones, each of which is treated as a part project and the cut-fill transition process is looked upon as providing service to the part project so that a dynamic system of a dispersed event is abstracted from the construction process of the whole earth/rock cut-fill transition construction. Likewise, the queuing network model and circulation network model can also be established. The simulation process is in fact to determine the start time of cut-fill transition and the finish time of completion for each of the cut-fill transition blocks. Through simulation, the following problems can be killed: The extent of comprehensive impact of environmental factors like rains on the earth/rock construction progress; the earth/rock work completion process with the scheme of different transport machinery complement and cut-fill transition plan of material yard; machinery complement and the availability thereof; process and progress with restraints of different cut-fill transition planning.

Based on the above simulation achievements and through comprehensive comparisons, the optimum construction scheme on the principle of the total cost being lowest can be selected and with the overall time schedule being worked out.

5 Conclusion

Should a cost engineer grasp the simulation technique, he could get rid of the

traditional method of using the cost database and quota method to calculate the engineering cost and ascertain the time of construction and change the detailed and complicated heavy labour into light and merry games. Besides, the results will become more convincing and particularly to the adoption of new techniques and technologies, cost engineers will no longer feel ignorant and at a loss. In case the cost engineer knows the rationale of new technique and new technology, he can perform tests on the computer through simulation to determine the engineering cost and construction duration for a project. With the simulation technique available, it is a good blessing to the decision makers, who can free themselves from obscure and boring documents and see the construction process which is lively as if it were true by simply sitting in front of the computer, and attained the simulated engineering cost and time of construction at the end of the demonstration, which will provide a powerful basis for decision makers.

Some institutions have recognized the advantages and development prospect of simulation in determining engineering cost and construction duration and carried out some research work thereat. But so far this technique still remains at the stage of assumption and study and has been distanced considerably from practical application. If a perfect engineering simulation system can be developed, it will be no doubt a great contribution to the field of engineering economy, because this method is like being in the objective construction site, the capacity of objective labour and construction machinery should be used, with quality, safety and environmental standard as the target, and with the material performance and construction technology and method as the foundation, to objectively mirror the construction and management cost of the engineering project and rationally ascertain the construction duration of the project around the economic goal. The engineering simulation system upon the completion of development will constitute a setup reciprocally supplementing and supporting other methods of determining of engineering cost and time of construction.