6D+ CONSTRUCTION MODELLING – EDUCATION

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Abstract

It is a rare situation when accessible technical potentials of innovation are anticipating recognized needs. Construction site is an ideal field for multi-dimensional modelling of objects and processes. Construction site is the point where 3D space, time, cost, power are meeting each-other together with countless other dimensions of completion. Vision of managers and craftsmen walking along a construction site negotiating and disputing while moving in a half-real half-virtual space projected on a small translucent screen attached to their safety helmet tends to be less and less destined to the world of video games and of out-of-reach day-dreams. The paper is addressed to some special aspects of Construction Modelling and to the question why technical possibilities of virtual construction (multi-dimensional construction modelling) seem to be rather a threat in eyes of (some) stake-holders of construction projects than a vivid tool to be utilized.

Keywords: construction modelling, computer applications, education
(Construction Planning and Organization)

Preface

University tutors and practicing managers having more ten years of experiences in fields of construction and not rarely in use of extensive computer applications, can approve the age old phrase saying: „Nothing new is under the Sun”. Multidimensional modelling is also not a new development or idea either it is said 3D or 6D or XD. Colourful animated presentations are common tools to persuade stakeholders or to demonstrate declared or implied aims of project activities. We have seen a lot and not a few of us had produced numerous ones of that kind. Theoretical and practical capabilities and available facilities of up-to-date computer applications are less and less astounding us – especially knowing the enormous bulk of work, the millions of working hours endeavour of thousands of engineers. And at the end, seeing clearly that brilliant inventions have frequently turned to a pure financial question – better said to a selling or not selling product on the Market – our enthusiasm keeps fading on.

Ultimate inspiration to study these tools of planning and representation again has been laid on us by seeing elementary need and industry of our young students to use or to have access to a virtual world that gives them opportunities to „realize” their imaginations, to „play the game”, to visualize that can be visualized, to manipulate, to create, to communicate, etc..

Their desire of this kind has a great distinction compared with natural curiosty and similar wishes of any children ever lived on Earth: Now, it can be turned to reality…

1. The 6D+ space

When discussing developing potentials of computer applications at modelling construction in a multidimensional space we do interpret the six dimensions proposed in the heading of this paper as follows:

3D represents the building, the object, the entity itself that is the aim of planning and/or of construction activities.

Time is interpreted as extent or moment of time during completion, aging of material and of structure, or the whole life-cycle of the given investment – from the smallest to the widest extent. It represents the general dynamism of changes in characteristics under consideration;

Force (Power) dimension – in different contexts – can be read as all internal and external effects such as natural and/or social forces and behaviours acting on the building (both in object and in process sense). It can represent either deadloads or loadbearing capacities of the structure or of its close neighbourhood, or – in the widest context – it can embrace all charges the structure itself or its operation exposes on the environment;

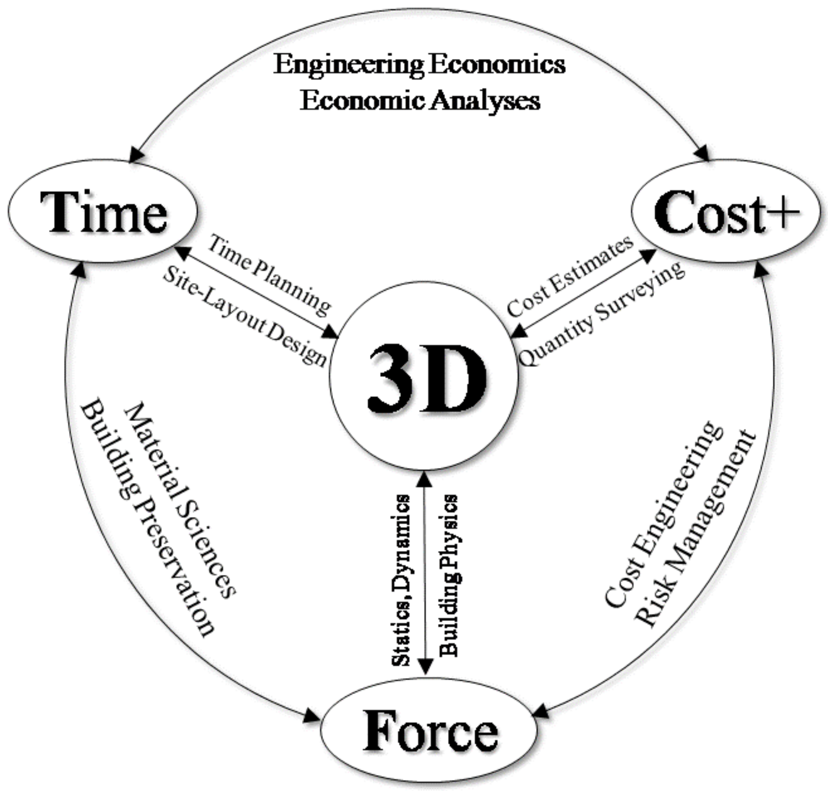

fig.1: The six dimensions and sample areas of education in the 6D space

Cost+ incorporates – beyond direct financial resources – all other efforts that is needed for completion of the construction project. Indulging some contradiction with definition of resources – such as: „resource is anything and everything that is needed and is limited in access", that is being to be managed, in which context space, time and force may also act as resources – we may consider all human, material, mechanical and mental resources essential for completion, but being within the competence of Contractors contributing to execution.

The „six(plus)" dimensions are desperately matching each-other at the site and phase of completion. Though this earlier is an age-old recognition – due to mainly didactic reasons – syllabi and education at universities are organized around some slices or sections of this multidimensional space (see fig.1). Strictly limited financial- and time-frames of education – with less and less capacities for practial experiences during training courses – are also not promoting the development of required comprehensive multy-dimensional approach and problem-solving abilities of young professionals.

2. Available tools of modelling

Computer Techniques, Telemetry and Telecommunication have developed much within half a century providing world of more and more reality-like virtual reality (say: „modelling"). Scientific and practical achievements of various disciplines are rapidly incorporating to every-day practice.

- That had been a gentle desire – all students to have their own personal computer or laptop with unlimited access to the world wide web – some years ago, now is a tangible reality;
- Nearly all scientific and algorithmic problems and models have been adapted to and built in computer applications;
- Electronics – as a kind of artificial intelligence – is integrated in appliances of every-day use (sensors, controllers, processors);
- Some years ago still unimaginable amount of information can be stored and is accessible in hardly a sensible short time;
- Scientific and economic databases are interlinked to each-other in international networks;
- Standardized software applications are assisting daily life. Communication throughout the whole economy and at administration is going to be totally computerized;
- Global – and engaging local satellite – positioning systems do provide exact localization within the range of centimeters;
- Fast and accurate devices serve sharp and vivid visualization (either printed or projected);
- International programs are promoting student and staff exchanges for technical experiences and research co-operations;
- Education systems and professional certificates are tending to be standardized moving toward global communities of practitioners;
- Globalization – and within that, european integration – keep eliminating shackles of spreading technical innovations, know-hows and technologies;
- etc..

Nowadays not an architectural design or an engineeric drawing can be delivered (approved and accepted) without using some kind of CAD system. Bids (cost estimates) and invoices (surveys, audits) are nearly exclusively processed by some standard computer applications.

Telemetry at site surveys is commonly used. GPS, Laser Navigation and Remote Control are real options for operating fleets of heavy equipment (at extensive earthworks). Automated, self-controlled equipments – such as (tunnel-) boring machines, welding machines, computer assisted cranes, unmanned production lines, robotics (at manufacturing) – are also common tools in Construction Industry too.

Not one single CAD system developed for architects and engineers is furnished with features to handle more and more aspects of a Design Project either in 5D (e.g. GraphiSoft ArchiCad [1], AutoDesk AutoCad [2]). Sophisticated applications are assisting structural design (Axis, FEM Design), time- and cost estimates (spreadsheets, databases), project planning (Primavera [10], MS Project [9]), and so on.

So, the 6D+ space is deeply elaborated, studied, controlled and monitored by tools of up-to-date computer technology – albeit not always in 6D+ integrity, but in slices … until start of completion … till the end of design phase. Processes of execution (completion) is rarely modelled (simulated) in such a deep detail, in such a comprehensive context.

How is that above results are not integrated and are not commonly used at construction sites, during execution of building projects? Construction is widely known one of the most power (resource/effort) consuming industries of the economy, with the highest potentials of any savings. What is the problem?

3. Troubles of application

Interviews and consultations with experts and contractors practicing in Construction had pointed at manifold aspects of difficulties with above mentioned applications at construction sites. Their most frequent objections are:

First of all, contractors usually do not have staff for such a job. „Who would pay for that?" – they say. (Albeit site engineers nowadays are using computer applications almost each day, and costs of necessary software and hardware system is generally dwarfed by overall costs of typical construction projects.)

Secondly, this kind of investment would be financed from the overheads, that is from the profit of contractors, and increased overhead costs are rarely accepted by the Client. So, it can be considered at above a given project size and/or at above a given level of risks. (For routine works, for simple jobs modelling technique of this kind hardly has any advantages.)

Thirdly, this kind of models would have any use only if tracking progression of works would be managed also by these tools. That would lay an extra „administrative" load on local staff. (Site engineers do have a lot of administrative jobs when registering daily progression in building records. It also tends to be general that Clients require daily photos and web-cameras installed on tower cranes to review and to check progression of project from a far location.)

Fourth is, typical clients are usually impatient and are reluctant to pay more time and cash for such a preliminary job i.e. for modelling completion in advance and/or simultaneously. (During only the last year the author had met three great reconstrution projects in and around Budapest where site management had been one of the key aspects of evaluation of bids during preliminary procurement procedures.)

It is also a significant burden on contractors, that computer applications (hardware elements and software systems) are rapidly and permanently changing generating high regular costs of upgrading and updating. Higher level of such expences excludes small – even middle – range companies from competition on the market. (Use of sophisticated modelling and/or so called „experts systems” can be expected rather at bigger companies.)

Next is, plans are frequently changing during period of completion (due to the relatively long time, providing opportunities for decision makers and for the Client to change their minds in various aspects of the building itself or its future utilization), and are not rarely not finished (parallel planning), or inappropriate for multidimensional modelling. (That is exactly the reason why computer aided multidimensional modelling would be desired and be essential. Especially, considering the fact that in our days nearly all designs, plans and documents are processed and communicated by some computer applications.)

Furthermore: What new information could be gained via these „new ways” of monitoring or modelling, more than experiences of professionals having been in Construction for more tens of years? Assuming acceptance of these needs have all the time and work been estimated by anybody that is likely necessary for to elaborate a „multidimensional” model of completion of this kind – including temporary conditions, structures, equipment and other considerations within a relatively short time? Moreover, managers, participants and decision makers are occasionally not ready to make any decision since they are not always in possession of the knowledge of all necessary data and circumstances to pro-act or counter-act properly.

Multidimensional models – such as any models – must never be the aim, but the tool of problem solving!

Our purpose with this research is primarily to test abilities and capabilities of available tools and applications of modelling. We also would like to answer the question if we have really arrived or not at the age when integrating available modelling techniques we can help efficiency of on-site management, minimizing potential risks and losses or any disputes and conflicts during and after completion. We would like to find real reasons why the so called modern electronic tools of visualization have not conquered the building site yet, and seeing potentials in them we are trying to find the most effective way of overcoming these barriers.

4. Attacking upon barriers

Introducing multidimensional (6D+) approach and modelling into daily practice of education and hopefully later to reality of Construction – just like any project – necessiates thorough studies and proper designs of tools, processes, and states of development. At Department of Construction Technology and Management of Budapest University of Technology and Economics (BUTE DCT&M) a new co-operation is forming between students and staff members to prepare a platform for future development. Areas of our efforts can be arranged to six main groups as listed below.

4.1 Modelling equipment, tools, products and technologies, forming a free database of 3D construction models

Since students do learn use of computer applications such as MicroSoft Office, AoutoCad, ArchiCad and so on by the curricula [4] of the university they are frequently using these softwares when elaborating their assignments of construction management and site layout design too. And they are also employing past results of such design activities (of students of previous years) but copying and accepting them frequently without essential critiques and prudence. A lot of improper solutions, misproportional and false drawings, incorrect descriptions do keep returning in their homeworks without any change year by year, despite of all and any correction, warning or menace performed by the tutors. (It was the ultimate reason why we had joined to the popular movement of 3D – read: „multidimensional" – modelling).

As part of preparatory work we do offer for capable students – as an alternative assignment (sub-task) – to elaborate correct 3D model of a single equipment or arrangement typical at construction sites. Correct representations resulting from their thorough work revised and tutored by staff memebers of BUTE DCT&M are (will be) uploaded to home page of the Department. We do expect these uploads to serve as reliable schemes and as a free database later to be opened to the wide Public (e.g. published via Google Sketchup Fans' Community).

4.2 Developing standards for modelling and for elaboration of details for to develop effective computer models (considering processing time versus storage capacity)

A significant lesson of our modelling efforts is that we have to determine sufficient size (details) of elements of models to be elaborated. An over-elaborate element may disutilize the whole model by slowening re-generation of images, making motions broken or freezing the computer. A detailed 3D model of a heavy construction equipment – for example – can be demonstrative when the aim is to study the architecture and abilities of the given equipment, but inserting that model in a site layout design in series or in plants may result in corruption of the software application due to overloaded processor or surcharged operative memory.

It is also a recent endeavour to harmonize standards systems throughout the whole European Community and over the Global Economy. Properly constructed and widely accepted free representations of this kind may form a basis for elaborating standards of 3D (or even more dimensional) notation of tools, equipment and other elements (reflecting their features, needed room of operation, working abilities) when integrating them in construction models.

4.3 Analyzing and searching algorithms for modelling temporary conditions and behaviour of structures and equipment for to develope interactive construction modelling systems.

The most challenging task in the program is modelling behaviour of temporary structures and developing algorithms for to describe motion and progression of equipment, strutures, components, etc.. We can consider either the location and shape of a ditch for foundation works or a trench for public utility works. It can progress, move, reshape, decline. Ramps or walls of it may have some loadbearing capacity, humidity and stability – permanently changing by time. A scaffolding or a formwork can also evolve and move along the structure while – at the end – it is removed. Walls of high-rise buildings can be built horizontally, vertically, in sections, or as curtain walls, etc..

4.4 Searching data structures to find communication interfaces between software systems

Early results and experiences of our research indicate that efforts on developing a supersized „almighty" software system would hardly produce positive return on invested resources. Specialization of skills on our domains and industries contributing to construction projects are too deep and too wide to integrate them in one single system.

It seems to be a more promising way of integration to find proper interfaces between modules of high quality specialized software systems and to develop a kind of common platform for software applications.

Also a meaningful lesson of studying recent online applications is that most effective way of developing extensive knowledge bases and data sets is utilization of creative potentials of the Public. We can consider the enormous knowledge treasury accumulated in (and by) free online applications like Wikipedia, Strukturae, Google Earth – and their satellite applications like Panoramio, Sketchup, etc.. (This very last appears to be a promising tool for developing and manipulating 3D objects when modelling construction sites [6])

4.5 Testing potential utilization of 6D+ models at real construction projects

It is a sub-task of the research program best fitting scientific interests of our Department and our curricula sith typical diploma works of our students are aiming at development of time and/or cost estimates, site layout designs, and analysis of some selected aspects of completion of a real on-going construction project. Students do have to study technical documentation, visit the site, consult on-site experts, make photos, develop variants of technical solutions.

This spring was the third semester when more students had voluntarily applied tools of multidimensional modelling as a facility of elaboration or as special field to study [3,8,12].

4.6 Testing and quantifying benefits and synergy of multidimensional models

This assignment within the program is not for to prove utility of multidimensional modelling. We are sure of that. Main expectations of this activity is to find and highlight the most effective ways of developing and using multidimensional (6D+) models. Findings would be aggregated in guidelines and suggestions where, when and what to elaborate in wat a detail.

Evaluation of results necessiates more – say statistical – experiences of real applications. It is a research job – we think – for the future.

5. Potential (expected/aimed) utilizations

Since „a human is a visual being” we see countless fields of utilization within Construction-related specialities (professions, interests) too. To suggest some examples of them:

5.1 Training and Education

As university tutors of construction management we do frequently face the phenomenon that young students with slight experiences are eagerly needing visual demonstration of technical and managerial situations. Pure words – even engineeric drawings – are usually not enough to persuade them.

The earliest and the most influential achievements of multidimensional (6D+) modelling are expected on fields of education. The most enthusiastic consumers, users and employers of these techniques will surely grow up from students of new generations having met these tools in early years of their studies, in the most determinant period of their professional career.

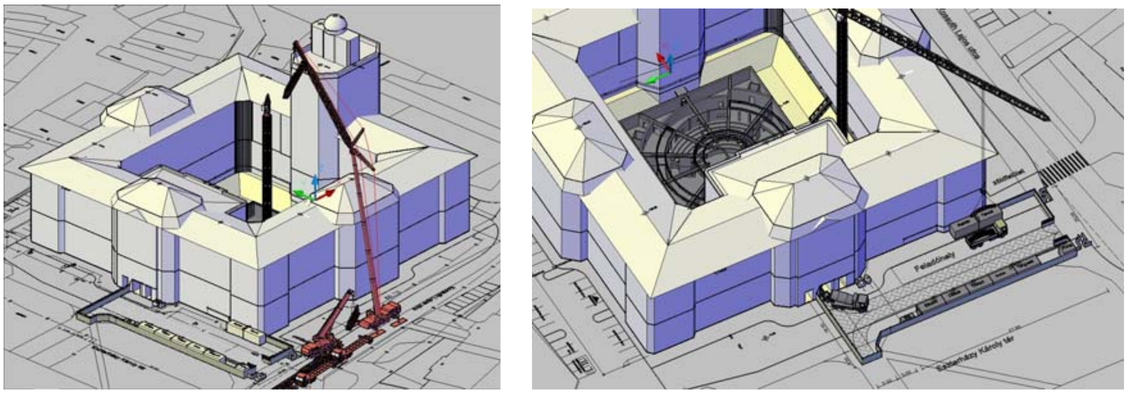

fig.2: Site-layout details from diploma work by Tibor Bajkai
student of Civil Engineering, BUTE DCT&M, 2010
(original drawing, using facilities of AutoDesk AutoCad)

5.2 Design and Architecture

Visual nature of architecture is out of question. Nowadays it is also a trend that architects do use solely computer softwares to elaborate details of any architectural drawings. Free-hand drawings tend to be restricted to free consultations or sketching up concepts only. Problems with the earlier drawings is that users are frequently focusing their attentions to the final product (to the final structure), while processes and potential technical conflicts of their execution are not rarely covered by the spectacular images. „3D concept" (6D+ approach) is practically not extended to the period of completion [1,2].

It is another kind of problem that computerization of design processes gives designers a kind of freedom to change (details of) their plans quickly, without difficulties. Despite of – or due to – electronic linkage between contributors of design process plans (architecture, statics, building mechanics, electric works, HVAC system) are frequently not synchronized and/or changes are not thoroughly transfered to all related drawings. Lack of synchronization and conflicts of plans and those of specifications are frequently revealing as evidence too late, during completion, on the building site.

5.3 Controlling and Monitoring

The highest break-through power of applying comprehensive multidimensional models we do expect in fields of Controlling and Monitoring when progression and variances of execution is traced in a real-time manner, permanently. Instead of reading endless lists of alpha-numerical data and charts, planned and actual progression can be projected either in the same view, where variances could be displayed in the most eye-catching way. Key question is the efficiency of processing the huge amount of data that also can be improved by applying data-processing systems widely applied at manufacturing, and at forwarding industries.

Displaying 6D+ on a 2D screen of a computer can be managed more handily and with less difficulties than one would guess it at the first sight. The following arrangement proved to be efficient for clear understanding: Actual view of the first three dimensions (Euclidean space) is displayed on a 2D screen while 3D „feeling" is provided by motion. Position of the „2D camera" can be set optionally. This facility is provided by all 3D modelling softwares typically used by constructors and architects. Positioning the camera by motions of the head of the user and projecting the proper view on a translucent screen (head-up display) attached to a helmet for to provide the sense of a virtual space is already an available technical solution. 4^{th} – and usually the ruling – dimension is Time. Assigning time position can be managed by simply moving a pointer along an appropriate time-scale displayed on the screen. 5^{th} dimension is Force (typically loadbearing capacity or aging of structure) indicated by colours (e.g. red highlights the most problematic zone, yellow indicates be careful, green reads everything is OK). It proved to be expressive indication of potential problems at foundation works, earthworks and structural works. Conventional color coding system used at stress- or strain diagrams are also applicable. 6^{th}+ dimensions are resources (human, mechanical, material, financial, etc.) quantified either in natural units or cash and displayed on traditional barcharts or hystograms at a separate area of the screen [8].

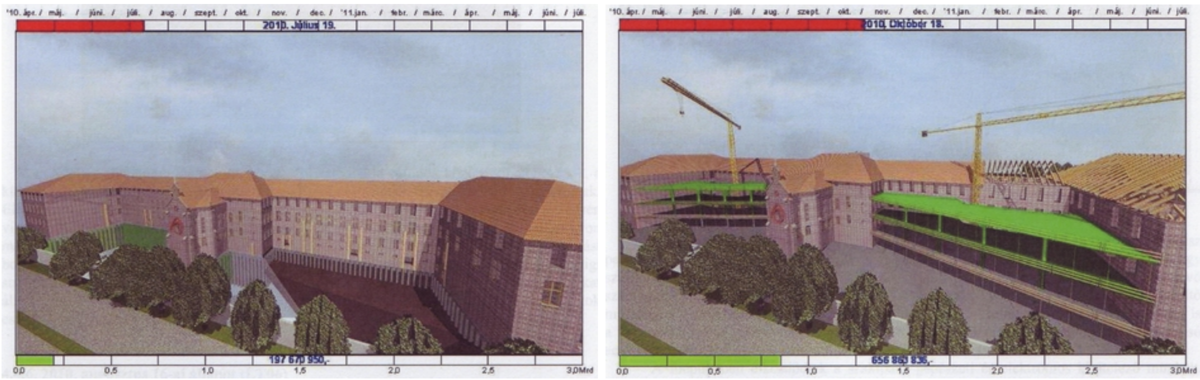

fig.3: 6D Schedule-representation details from diploma work by Viktor Horváth
student of Civil Engineering, BUTE DCT&M, 2010
(original drawing, using facilities of Graphisoft Archicad)

Also a great challenge of research is how to relate the five other dimensions to the ruling one. That is, how to generate automatic update of views when, for example, position of time pointer (or any significant aspect of the project) is changed – including image of the building (sorrounded by temporary structures and equipment) together with other characteristics, such as location, size, age, strength, deformation, temperature, humidity, etc. of it.

5.4 Risk Analyses

Comprehensive (6D+) models are most of all expected to predict and to indicate potential conflicts for to provide possibilities to plan counter-actions, to minimize chance of risk events and/or to minimize unintended consequences of them. It is an age-old recognition that the seemingly least problematic factor may inhere the most destructive danger („misleading sense of safety”). Up-to-date Risk Management embraces analyses of the whole project from emerging the idea through design and completion to life-long utilization [11].

Construction projects are exposed to any risk most of all during the period of execution. The highest stresses are exposed on structures during completion. Any failure then has the highest potential to cause serious damages in property or in life. (See statistics of building failures and accidents [5])

5.5 Optimization

6D+ modelling implies seeking „under-surface" and „behind-curtain" mechanisms, effects and motivations too. Developing logic of a model may advance understanding cross-relations and interactions between/among particles of the whole. Beyond integrating up-to-date results of Management Science (Operations Research) new tools of comprehension and of evaluation potentially encourage experts and scientists to develop new methods, techniques, algorithms and functions to increase utilization of available resources, targeting on the minimum of really necessary efforts. New optimization models and problems can be composed and interpreted. (Multi-Criteria Optimization, Decision Support.) [7,13]

5.6 Quality and Change Management

Site managers are responsible for coordination of contractors, sub-contractors, craftsmen and labourers having different skills, interests and education. Unambiguous communication (demonstration and representation) of aims and details of the project surely promote achievement of declared and/or implied goals.

A typical Client is usually not an expert of construction. Confronting him/her with difficulties of his/her newer and newer ideas of modifying plans of a contracted ongoing construction can help to keep the project on track, and to avoid future disputes over unintended results [11].

5.7 Health and Safety Management

New concept of on-site Health and Safety Management extends labour safety consideration back to planning phase when designs of structural elements are being elaborated. After the new profession of „health and safety coordinator" [5] has been brought to practice – as a consultant from basic functional concepts to management of constructed facility – designers also have to consider feasibility of execution of their plans. 6D+ project models may draw increased interest in safety aspects of Construction too.

5.8 Conflict Management

Construction projects generally expose high loads (traffic, vibration, noise, etc.) on the close and near environment of construction site. Careful design of logistics and of temporary conditions together with overwhelming communication of project goals to the public are main tools of conflict management as preventive means. Explaining and introducing processes of construction (what is going on, why, and during what a period) may anticipate resistance and hostility of social environment especially of the close neighbourhood [11].

5.9 Site Management

New possibilities of using high performance materials and equipment inspire clients and designers to build extravagant structures (enormous spans, surrealistic forms, false imbalances). Erection of structures of this kind usually includes lifting and manipulating irregularly heavy or oversized loads. Sometimes existing adjoining structures or the close neighbourhood expose extra risks on construction processes, such as narrow site, underground works, protected architectural heritage, sensitive or dangreous conditions, limited accesses, maneouvering heavy equipment in a dense area usually under heavy traffic, and so on. Detecting or – as intended – indicating potential technical conflicts and difficulties in advance can effectively contribute to determination of appropriate solutions and helps to avoid embarrassing on-site improvisations and unnecessary idle times.

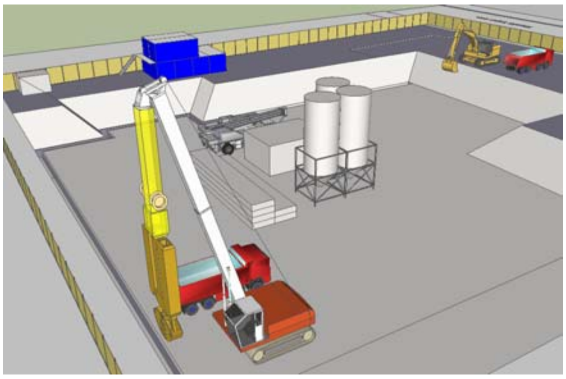 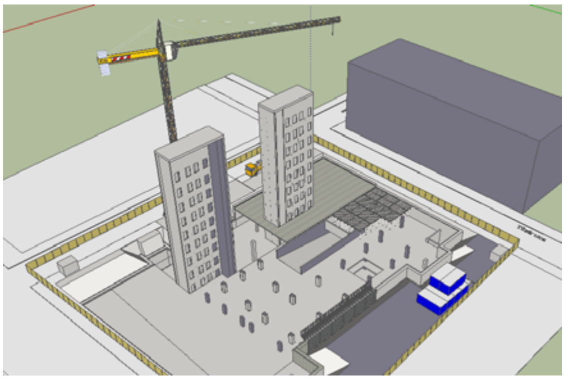

fig.4: Site-layout details from diploma work by Beatrix Strauss
student of Civil Engineering, BUTE DCT&M, 2011
(using facilities of Google Sketchup, equipment models downloaded from INTERNET)

Summary

In this paper we intended to report of our endeavours to develop a free interface and a free open database for to assist education and practice of Construction Management. Introducing term of 6D+ modelling we had reviewed potential utilizations and frequent objections against multidimensional representations during period of execution (completion).

Work has just begun. Here we do take the opportunity to call potential partners accepting the above aims to co-operate in developing fundamentals of a hopefully comprehensive and free open database for modelling on-site construction situations and processes. We hope by these tools we can increase efficiency of study, education and practice of our common profession, Construction Management.

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