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INTEGRATED INFORMATION TECHNOLOGY OF DESIGN AND CONSTRUCTION MANAGEMENT

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Abstract

The paper deals with integration of the data processing problems in the complex "design - construction" process, aiming to minimize the total time spent on data processing. Sequence of the basic tasks under observation is: quantity surveying and estimating, drawing up the technological models and calendar plans of construction (including labour and cash flow schedules), purchase orders of the materials and control of material usage, control of execution of the tasks and fixing the norms (feedback). Theoretical approach to the problem serves as basis for elaboration of the classification system, which depends on the task management and distance of the time horizon and allows to rationally group and aggregate data. Construction project resources (materials, labour, finance) and construction works process centred models, as well as formal structures of the informational models (hierarchical, network-, matrix- and relation models) are discussed.

1. INTRODUCTION

Integration of the data processing tasks is in the first place obstructed by the variety in design, procurement and construction management schemes. However, management tasks require generally the same project data in various points of time, which is often grouped using different characteristics or is differently aggregated. Building structure designed by architect and civil engineer could be modelled as hierarchical (tree shape) model. For timetabling and modelling work in the technologically consecutive order, suitable network models were developed. Construction economy could be best analyzed by matrix models. In prosperous management, transition from one data grouping, from one aggregation, or from one structure to another, is usually accompanied by new input of the whole data. To guarantee input of the initial data on one occasion only, we attempt to formalize all possible connections and attributes of the elements, belonging to the object under consideration. In order to determine the basis of the model, where from the rest of the outputs could be attained by linear variation (analogy to matrix algebra), norms and typical schemes are used.

Next, the construction project is presented, using different aggregate models, which represent different connections and attributes of the elements. The discussion is valid in the first place for buildings and services and for their functioning, but could also be extended to be applied to the rest of construction industry.

2. MATERIAL RESOURCE STRUCTURE OF THE INFORMATIONAL BUILDING MODEL

In principle, the material resource model of a building, is a traditional project of this building. From the management informational aspect, it could be viewed as tree-shape aggregate structure. (Fig.1) Data is generated in design phase according to the scheme starting from the top, detailing and specifying the elements of an aggregate in an increasing mode. On the uppermost level is the building as a complex (C.B.), which satisfies some functional requirements stated in the project. Complex consists of separate buildings (B) and facilities (services).

Building (second level on Fig.1), in its turn consists of building elements: foundations, external walls, internal walls, slabs, finishes, etc., which are marked on Fig.1 as E.B. Element of a building consists of constructions (C), semi-manufactured products (S.M.P.) and materials (M) or combinations of the above. These material resources are divided between three levels due to the requirements of differentiating productional and informational cycles in construction industry. For illustration, refer to Fig.2. Project determines the external wall of panels and bricks. Panels are produced by the contractor himself, but in separate workshops. Consequently, the required number of panels (C) must be known, as well as the quantities of semi-manufactured products (S.M.P.) and materials (M) to produce the panels. Also the quantities of materials to produce the semi-manufactured products must be known.

Following conclusions could be drawn from the presented discussion:

- detailing and specifying data is required from the top level downwards in design phase with every element of the lower level having ascribed characteristic of the direct upper level;

- when classifying material resources, every resource should be described by the characteristics, which indicate, if it is a construction, semi-manufactured product or material.

If the above aspects were taken into account, then in construction phase, when data is formed from the bottom level to the top, it would be possible to form resource orders in requisite groups as addition to quantity surveying, estimating etc.

3. ORGANIZATIONAL / TECHNOLOGICAL STRUCTURE OF THE INFORMATIONAL BUILDING MODEL

Unlike the above given material-resource structure which describes building as composition of physical elements, following observation focuses on description of the building through works and activities necessary for its erection. Realizing, that even using computer aided design tools, only very few operations could be automatically processed from dimensioning elements of building to the descriptions of works related to these constructions, we choose a traditional scheme. This means that a building will be for the first time specified by the quantity surveyor. It is not of an interest, if it happens in design or contractor firm, before or after tendering.

Objects of our interest are the principles of classifying and structuring. Let us start from the most detailed data presentation, presuming, that aggregation could principally be automated using more or less unified schemes.

Works are specified in greater detail on the level of unit prices. Catalogues of unit prices (SNiP and ERER in the former USSR, Dean's catalogue in USA etc.) differ in various countries, but these differences are not in conflict in essence. As the number of unit prices reaches tens of thousands, for planning goals, numerous aggregations are needed. According to the practice, at least the following aggregation structures should be differentiated: cost planning, labour planning, calendar planning, spatial planning of quantities.

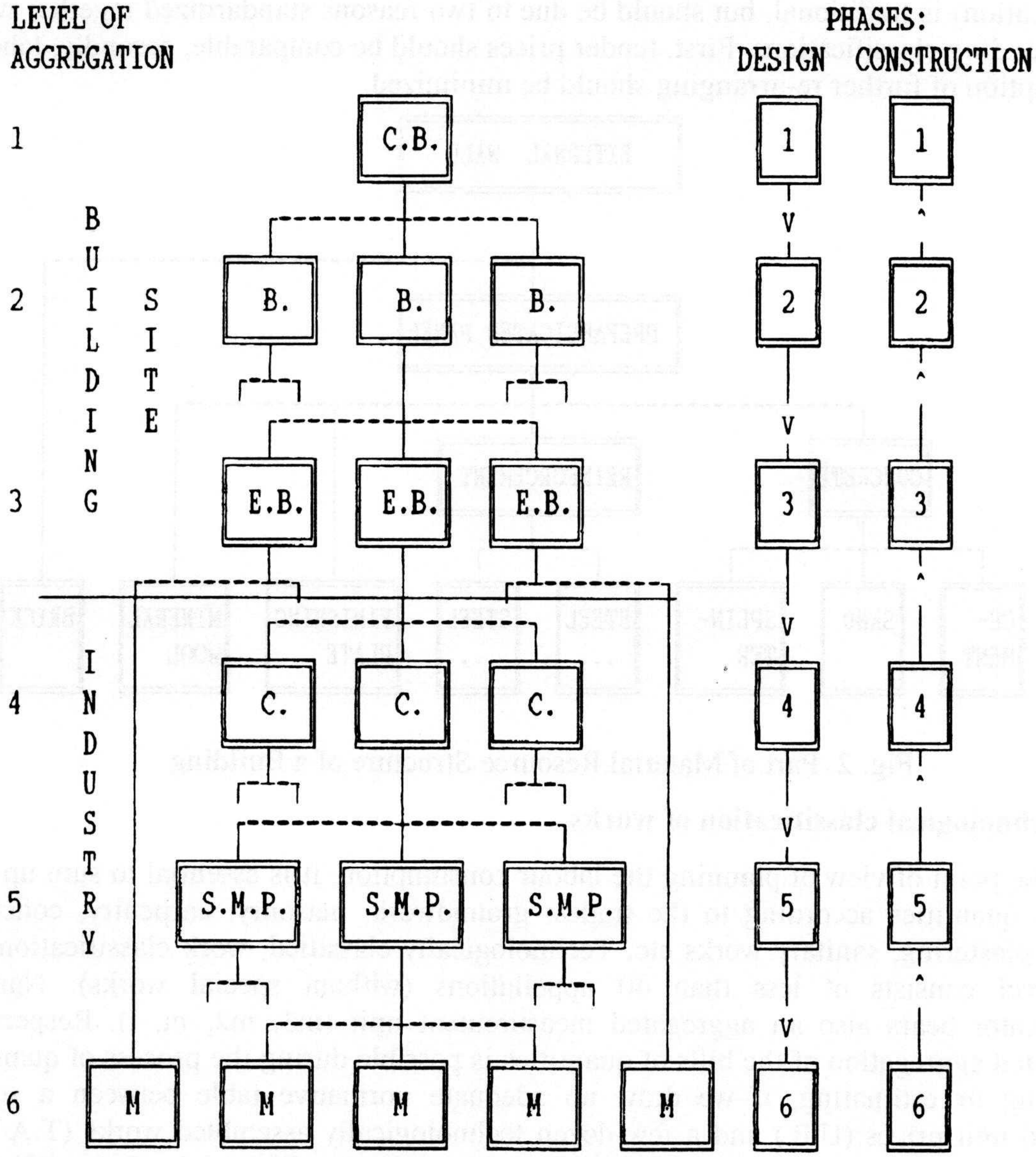

Fig. 1. Physical Structure of a Building Complex

Next we try to assign a formal structure to the given list, so that further rational data processing algorithm could developed.

3.1 Structure of the cost plan model

Referring to the previous scheme on Fig.1, we can claim, that unit price work description specifies assembly of the material resources into the building on the forth, fifth and sixth levels, which describing the quantities, are aggregated into construction elements (third level). According to the specialization of the design, drawings and specifications, bills of quantities and estimates are grouped by the classes of works: construction and special works (water service, sewage, electrical installation, communication, ventilation etc.). On Fig.3, these are marked as work classes (C.W.) on second level. In former USSR, elements of buildings were grouped into two parts: substructure and structure (Fig.3, PB on second level). Such classification proves to be very comfortable when rearranging the groups further. Also special activities have sub-classes (CSW), but these will not be discussed in this paper. To sum up, we can say, that observed structure (basis of the classification) is traditional, but should be due to two reasons standardized together with corresponding classifications. First, tender prices should be comparable, secondly, labour consumption of further re-arranging should be minimized.

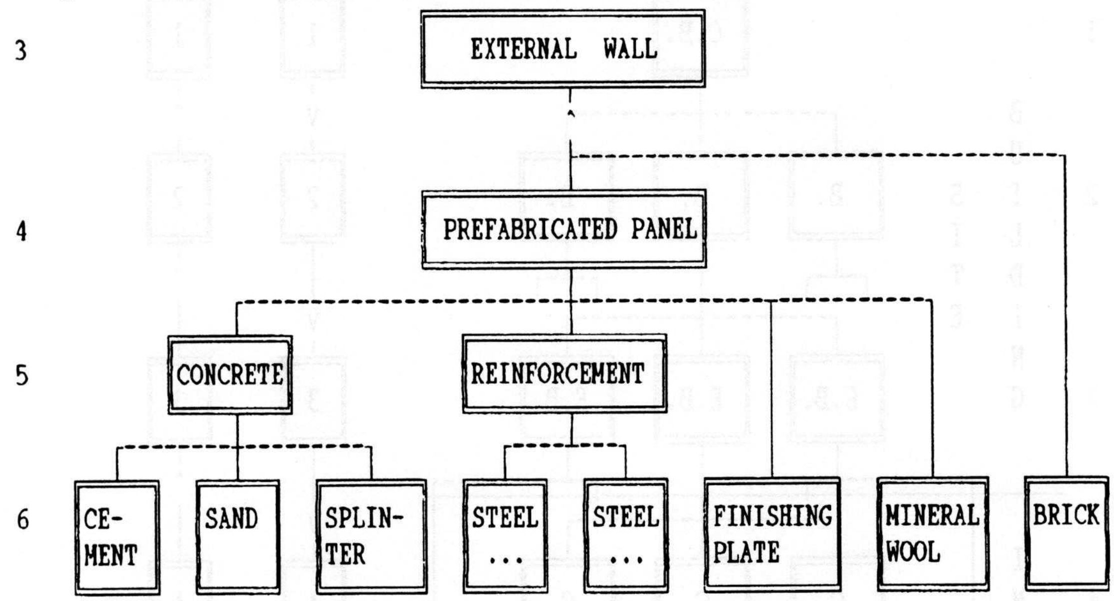

Fig. 2. Part of Material Resource Structure of a Building

3.2 Technological classification of works

From the point of view of planning the labour consumption, it is essential to sum up the bills of quantities according to the trades: groundwork, masonry, carpentry, concrete works, plastering, sanitary works etc. Technologically classified, work classification on this level consists of less than 40 appellations (without special works). Named classificator bears also an aggregated measurement unit (m3, m2, m, t). Respective automated aggregation of the bills of quantities is possible during the process of quantity surveying or estimating, if we draw up adequate normative table between a score hundred unit prices (U.P.) and a few dozen technologically assembled works (T.A.W). This means that computer groups together technologically alike works from different bills of quantities and estimates. The construction technology being conservative enough, with all contractors using the same unit price basis, could also use the same common classification of the technologically aggregated works and adequacy table. Referenced adequacy table (Fig.4, aggregation algorithm AA) should contain together with the list of the U.P. belonging to every T.A.W., coefficients of harmonization of measurement units of U.P. and T.A.W., which however may differ for some cases.

While dealing with the problem, the aggregation of U.P. and T.A.W. should be considered, which could be useful from the point of view of planning exercises. Large number of the unit prices depend on multiple parameters: class of the material (construction), building element (E.B., Fig 1.) where this material will be assembled, level of complexity of the element, its height, type of the equipment used, etc. Number of the requisites describing the process and greatly influencing the cost could reach a dozen. Labour content together with the duration usually depends on remarkably less parameters. These are represented by class of the material (C.M.) used and building element (E.B.), where the material will be assembled. For example, the range of the possible elements for masonry can include massive walls, insulated double walls, partitions, chimneys etc.; used classes of materials are blocks, silicate bricks, ceramic tiles, etc. Painting could be addressed to E.B. floors, walls, ceilings, windows, doors, etc. and corresponding C.M.: oil paints, water paints etc. It means, that technological classification should be based on scheme of Fig.4. If the classificators of the first and fourth level are commonly spread and inescapable in management practice, the use of the second and third depends evidently on computer experience and precision in productivity (labour content) accounting in the firm. In Estonia, T.A.W. classification is elaborated, which is detailed for one more level, so instead of second and third level, there is one level T.D.W. (technologically detailed work, Fig.4). Requisites, aiding the detailing are E.B.or C.M. or E.B.& C.M.

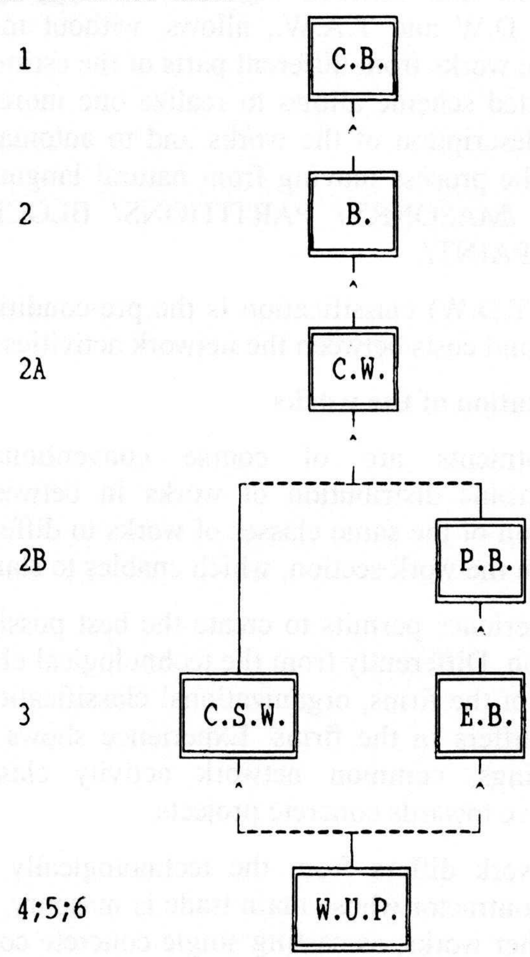

Fig. 3. Activity Structure of a Building

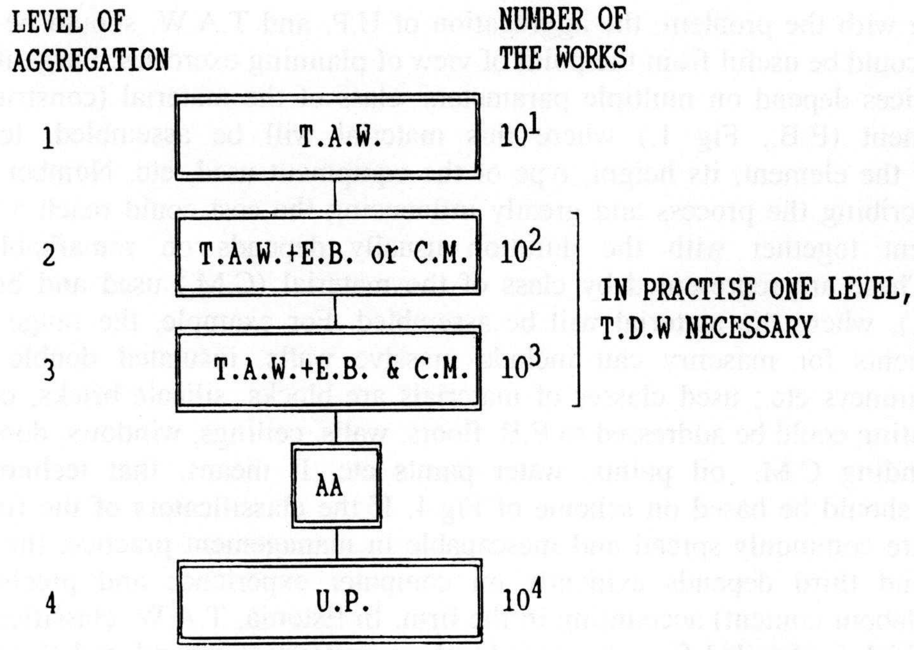

Fig. 4. Structure of the Technologically Aggregated Works

Such two level classification and referred algorithm of aggregation (AA), which harmonizes all U.P. with T.D.W and T.A.W., allows, without man labour, to group together technologically alike works from different parts of the estimates in greater detail or more aggregately. Presented scheme allows to realize one more goal - to formalize sorting out of the adapted description of the works and to automate shortening of the text. It is a step further in the process moving from natural language syntax to formal language syntax. Sample: /MASONRY/ PARTITIONS/ BLOCKS or PAINTING/ CEILINGS/ EMULGATED PAINT/.

At least two level (T.A.W.+T.D.W) classification is the pre-condition for redistribution of unit price level resources and costs between the network activities.

3.3 Organizational classification of the works

The classification appointments are of course conventional. Classifying by organizational characters means distribution of works in between groups and sub-contractors and also allocation of the same classes of works to different time points. For example, differentiating from the work section, which enables to start the next activity.

Long network planning experience permits to create the best possible classification for the works under consideration. Differently from the technological classification, which is more or less common to all of the firms, organizational classification is firm centred, as division of labour usually differs in the firms. Experience shows, that at least to the contractors erecting buildings, common network activity classification could be elaborated, naturally excessive towards concrete projects.

Organizationally grouped work differs from the technologically grouped works. An example of this could be a contractor whose main trade is masonry, while building brick building, it executes also other works, as casting single concrete construction, installing of reinforcement etc., which in technological classification are different works. Example of portioning the same work by different schedule could be electrical installation, which is done before and after finishes. In case of established division of labour, a table - form algorithm could be drawn, stating with classification which technological works belong to which organizationally grouped work. In the above presented example, to the work described as "envelope of the brick building" belongs masonry, but only for the external and internal walls of the building (not masonry for site enclosing walls), but also concrete casting for certain elements etc. Example of the structure of such table - form algorithm is presented on Table.1.

Grouping of works according to the organizational level should also have two levels: organizationally aggregated work (O.A.W.) and organizationally detailed work (O.D.W.).

Having in addition the above described aggregation algorithm (AA, Fig.4), which harmonized U.P with T.D.W. and T.A.W., is possible to atomize rearrangement of resources and quantities from the bills of quantities and estimates in between the activities of network and create presumption for their further timetabling.

Table 1

Algorithm of aggregation

ORGANISATIONAL CLASSIFIKATOR		TECHNOLOGICAL CLASSIFICATOR		C.W.	P.B.	E.B.
OAW	ODW	TAW	TDW			
23	01	17	01	23	1	16
			02	23	1	16
		22	07	23	1	16;17
			10	23	1	16;17
	02	17	03	23	1	15;16
			04	23	1	15;16
			05	23	1	15;16

3.4 Spatial break up of the quantities

Necessity of spatial break up of the quantities may occur in a firm intending to plan rhythmical work using line production method or to plan resource purchase as spatial-technological sets, considering rational stock on the building site. It is evident, that one cannot reach this objective using standard schemes or algorithms. To minimize total labour consumption of the engineer, quantity surveyor and purchase department, the building should be broken up into zones before detail survey of the quantities. This means, that summing up of the quantities according to the zones(W.U.P.,Fig.3) and related resources (C.;S.M.P.;M.,Fig.1) should be done in the course of drawing up the bills. In another way, Fig. 1 and 3 should have one additional aggregation level in between third and fourth or fifth or sixth.

3.5 Financial structure of the building model

The main problem is, when the cost structure, expedient in the course of estimating, could occur unsuitable in the financial planning (including cash flow) and accounting. This means, that cost should be restructured. For example, some costs, as overheads, calculated as percentage from the direct cost, should in the course of planning and cost control be viewed as direct cost, or part of the overheads should be connected proportionally to the direct cost etc,.

Without further detailed discussion, we claim, that having state standards of structuring the cost (price), it is possible to elaborate standard algorithms for demanded restructuring of the cost. On the contrary, if an attempt is made to create Euro-Standards for classification of the building cost, requirements of the financial plans must be considered.

4. CONCLUSIONS

Resources and different aspects of activities from the point of view of classification and aggregation were examined in this paper. They represent separate vertical hierarchical models of a building. At the same time problem of their horizontal links is still unresolved due to two aspects.

First, the data bearer should link works and resources by the addresses. The idea is, to have after the timetabling of the works, the resource (material) consumption timetabled automatically. Without computer technology, linking all the resources C&S.M.P.&M.(Fig.1.) to the work addresses W.U.P. (Fig.3) linking of this kind is out of a question. Using computers, these links could be fixed automatically in the course of preparation of the bills of quantities. The simplest way would be linking by the groups, as they have similar group code - E.B. (Fig.1 to 3). But more detailed linking, by every W.U.P. is possible. This assumes, that when drawing up coded bill of quantities, the work described by W.U.P, will directly be followed by its resources C.; S.M.P.; M. Secondly, the works when we succeeded in linking the resources, must be put into temporary consecutive order.

If the classificator O.A.W. was elaborated using the experience of network planning, the task could be solved using standard networks, which programm wise harmonize, grouped by O.A.W. quantities, with the topological codes of activities of the network. If use of the standard network is considered to be unreasonable, project manager should scan the bill of quantities of U.P. level and insert for every position in W.U.P three parameters: code of the work from the O.A.W. classification; topological code of the concrete network activity and the number of workers.

This creates the computer formed basis of the informational model, which needs to be stored. The rest of the data (cost and its components, labour content and duration, materials necessary to produce construction tasks and semi-manufactured products) could be derived by linear variations using U.P. norms and structural variations which were described earlier in this paper.

REFERENCES

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