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Budgeting in the Construction Industry

Calcul des budgets dans l'industrie de la construction

Budgetierung in der Bauindustrie

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SUMMARY

This report describes a computer model for construction management. Based on a systematic analysis of the offer, the construction schedule and the cost accounting a multi-period budget for turnover and a multi-period budget for the use of production factors are obtained by simple matrix multiplication. The two budgets are then further used for a multi-period financial budget, which includes balance sheets, profit and loss statements and statements of source and application of funds. It can be shown that the calculated budgets give excellent information for successful construction management.

RESUMÉ

Ce rapport décrit un modèle de gestion de la construction. Sur la base d'une analyse systématique de l'offre, du programme de la mise en œuvre et du calcul des frais, on obtient, par une multiplication simple de deux matrices, un budget des coûts et un budget des facteurs de production sur plusieurs périodes. Les deux budgets sont utilisés ensuite pour le calcul d'un budget financier analogue avec bilans, comptes de profits et pertes et mouvements des capitaux. Les budgets calculés donnent d'excellentes informations pour une bonne gestion de la construction.

ZUSAMMENFASSUNG

Die vorliegende Schrift beschreibt ein Modell zur Planung und Führung von Baustellen. Auf Grund einer systematischen Analyse von Offerten, Bauprogramm und Kostenkalkulation lässt sich durch einfache Multiplikation zweier Matrizen ein Mehrperiodenumsatzbudget und ein Mehrperiodenbudget des Verbrauchs an Produktionsfaktoren aufstellen. Die beiden Budgets werden anschliessend zur Berechnung eines Mehrperiodenfinanzbudgets verwendet, welches aus Bilanzen, Erfolgsrechnungen und Kapitalflussrechnungen besteht. Es zeigt sich, dass die berechneten Budgets eine ausgezeichnete Informationsgrundlage für eine erfolgreiche Bauabwicklung abgeben.

1. INTRODUCTION

Wer vorsieht, ist Herr des Tags
(He who foresees, rules the day)

Goethe

"Looking far ahead, in order to be able to act successfully in the immediate future" - this is probably a maxim every successful entrepreneur, economist or politician comes to obey in the course of time. For it is an old rule that the man who foresees the future works better than the man who is constantly taken by surprise by daily events. In this respect it is within the responsibility of every management to try to foresee coming events as well as possible.

This paper(1) describes a method for the management of construction projects. It can be seen from the literature that until now the construction enterprise has been neglected as far as management instruments are concerned. The present paper is a step towards closing this gap. Since large construction projects, where special management instruments can be used profitably, are often executed by a number of contractors, particular reference is given to the construction partnership.

2. METHODOLOGY

2.1 First step: Budget for turnover and budget for the use of production factors

The objective of this step is to estimate the turnover and the use of production factors as time series for a certain building. Therefore the following requirement must be met:

1. There must exist an entire performance list i.e. a list of all pay-items to be performed by the contractor.

2. Every pay-item must have its correct cost accounting i.e. for every item the required production factors (construction materials, working hours, machine hours) must be estimated.

3. There must exist a construction schedule which covers the whole performance time.

4. Detailed performance drawings must be available.

Under the above conditions the desired time series are obtained by the following three operations:

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(1) This paper is a summary of the original report to be published in 1978 by K. Fierz and M. Schneider: "Budgetierung von Baustellen", Institut für Bauplanung und Baubetrieb, ETH, Zürich 1978.

Operation 1:
In this operation the performance list and the corresponding cost accounting are analysed in order to obtain a matrix, which is organized as follows: The rows are labelled with the numbers of the pay-items according to the performance list. The columns are labelled as follows:

- turnover according to performance list
- working-hours
- engineering-materials (cement, gravel, reinforcement steel, etc.)
- operating hours of machines (excavators, crane, etc.)
- intermediate performance items (cubic metres of excavated soil, square metres of pavement, etc.)
- rents for machines independent of the operating time

The intermediate performance items can be defined as those pay-items of the performance list which are suitable for delegation to a subcontractor. No problem arises in estimating this matrix, since the needed information is created during cost accounting. It thus only has to be collected systematically.

Operation 2:
In this operation the performance list, the construction schedule and the detailed construction drawings are analysed to obtain a matrix which is organized as follows: The rows again are labelled with the numbers of the items according to the performance list, whereas the columns are labelled with time periods. According to the construction schedule the performance time of every item is estimated and distributed over several time periods. Let us assume quarterly budgeting. If 1/3 of item No. 500 of the performance list is to be performed within the 6th quarter of the performance time, the element defined by row No. 500 and column No. 6 will have the value 0.333. Since every item must be included in the construction schedule, operation 2 is quite a difficult task. It can be shown, however, that many items within a performance list have identical performance time distributions. This reduces the number of rows to be estimated to about 20 % of the number of items.

Operation 3:
In this operation the desired time series of the first budgeting step are calculated. We call the matrix of operation 1 "matrix of items and production factors" (abbr. MIP) and the matrix of operation 2 "matrix of items and performance time" (abbr. MIT). The desired time series are then obtained by multiplying the transpose of [MIP] by [MIT]. The result of this simple matrix multiplication will be another matrix called "matrix of production factors and performance time" (abbr. MPT). The rows of this matrix represent the time series sought.

The following example may illustrate the three operations (Figure 1): Let us assume the following aggregate performance list for a bridge.

- item 1 : excavation
- item 2 : abutment, piers
- item 3 : lane

In Figure 1 the transposed matrix of items and production factors is shown on the left, the matrix of items and performance time below and the calculated matrix of production factors and performance time in the middle. The result is obtained by the following matrix operation:

$$[MIP]^T * [MIT] = [MPT]$$

The digit of 2'000 working hours in the 3rd quarter is obtained by multiplying the 2nd row of the transposed [MIP] by the 3rd column of the [MIT]:

$$5'000 * 0.1 + 20'000 * 0.15 + 40'000 * 0.05 = 2'000$$

The above example is constructed. In contrast to it, Table 1 shows a section of a real matrix of production factors and performance time derived from an actual swiss highway construction project.

		excavating	abutment, piers	lane	1st quarter	2nd quarter	3rd quarter	4th quarter	5th quarter	6th quarter	7th quarter	8th quarter
turnover	SFr.	7.2	372	662	2.88	22.2	89.6	206.8	206.8	206.8	206.8	99.3
working hours	h	5	20	40	2.0	3.5	2.0	12	12	12	12	6
crane hours	h		1	2		0.05	0.25	0.6	0.6	0.6	0.6	0.3
excavator hours	h	1			0.4	0.5	0.1					
concrete	SFr.		160	320		8	40	96	96	96	96	48
steel	SFr.		144	288		7.2	36	86.4	86.4	86.4	86.4	43.2
pit timber	m^2		5.3	8.8		0.27	1.24	2.82	2.82	2.82	2.82	1.32

excavating	0.4	0.5	0.1					
abutment, piers		0.05	0.15	0.20	0.20	0.20	0.20	
lane			0.05	0.20	0.20	0.20	0.20	0.15

Figure 1 : Multiperiod budget for turnover and multiperiod budget for the use of production factors (digits of the left and middle matrix in 1000)

Table: Matrix of production factors and performance time for a Swiss highway project, currently under construction (all prices in 1977 SFr)

		Apr:Jun 1977	Jul:Sep 1977	Oct:Dec 1977	Jan:Mar 1978	Apr:Jun 1978	Jul:Sep 1978
turnover	SFr	1'164'831	1'928'094	2'361'621	1'607'917	3'043'977	2'999'997
concrete	SFr	30'250	115'305	339'380	228'755	445'366	537'643
reinforcement steel	SFr	18'215	99'422	412'096	277'754	530'505	563'505
gravel	SFr	6'886	9'303	13'430	36'353	83'606	69'755
hydraulic binders	SFr	0	0	0	18'283	18'283	0
stoneware	SFr	8'382	12'675	10'636	13'222	34'169	39'877
plastics	SFr	4'218	7'856	16'711	17'273	23'281	17'533
bituminous binders	SFr	284	6'228	795	3'804	3'972	2'512
remaining materials	SFr	31'828	31'521	19'335	19'965	30'152	25'778
shutter boards	m^2	1'646	4'075	6'585	5'479	8'756	10'157
trench sheetpiles	m^2	681	876	1'116	1'838	1'917	1'027
subcontractor excavation	SFr	70'150	115'935	53'817	0	51'543	41'904
" transports	SFr	362'816	575'769	384'027	113'575	234'032	218'521
" reinf.steel laying	SFr	0	13'182	60'766	38'544	76'955	87'667
" prestressing	SFr	0	0	0	0	0	0
" air-placed concrete	SFr	6'379	6'379	6'379	6'379	6'379	4'193
" rock blasting	SFr	1'631	2'473	17'993	13'491	49'232	55'511
" driving work	SFr	0	0	0	2'350	2'803	3'415
" edging	SFr	0	62	0	0	8'445	8'781
" pavements	SFr	785	0	265	1'315	14'074	24'723
" isolation work	SFr	0	0	32'345	11'933	116'493	48'361
" prefabrications	SFr	0	0	0	0	0	0
" sanitary work	SFr	0	0	0	0	0	0
working hours	h	15'197	22'677	26'509	21'564	35'136	34'461
operating hours building crane	h	0	270	270	270	540	540
" excavators	h	3'167	3'687	2'971	2'797	3'636	2'963
" pneum.-tyred crane	h	352	410	330	310	428	349
" road roller	h	0	0	0	0	214	174
" dumper	h	200	200	200	200	200	200
" backfill tamper	h	31	42	54	81	103	57
" high-press.pump	h	23	230	209	209	197	197
" hot-air equipment	h	0	0	874	875	0	0
" vibrators	h	82	215	185	169	378	342
" pumps	h	2'150	2'150	2'150	2'150	2'150	2'150
" small equipment	h	20	440	422	421	411	412
rents for building cranes	SFr	0	4'720	4'720	4'720	9'440	9'440
" " hot-air equipment	SFr	0	0	4'067	4'068	0	0
" " traffic signal systems	SFr	3'500	500	1'378	378	981	981
" " remaining equipment	SFr	6'839	6'839	6'839	6'839	6'839	6'839

2.2 Second step: Financial budget

Based on the one hand on the results of the first step and on the other hand on conditions given by law or by contracts, the objective of the second step is to calculate a financial budget. If a construction partnership is assumed, such a financial budget includes balance sheets, statements of income and statements of changes in financial position.

Evidence shows that the solution to the problem given can be achieved by starting from the structure of a traditional balance sheet. Figure 2 shows a simplified balance sheet of a construction partnership. Beginning with the assets, these can be divided into circulating and fixed assets. The circulating assets themselves are composed of liquid assets, receivables, stock of engineering materials and production not yet settled. The fixed assets consist of a performance bond, the stock of machines and the remaining fixed assets. Note that the performance bond is included in the fixed assets, since it will normally exist until the end of the performance time and accordingly cannot be classified as circulating capital. Finally the liabilities are composed of short-term and long-term outside financing and of accumulated profits. Note that there exists no privately owned capital, since in the beginning construction partnerships are externally financed. Privately owned capital is created in the course of time by retaining profits.

Any attempt to calculate the items of a balance sheet according to Figure 2 will soon come up against the following problem: Experience and evidence show that the balanced accounts of the circulating assets and short-term outside financing are subject to rather unstable development. Let us assume a suppliers bill is paid immediately before quarterly balancing. In this case the circulating assets as well as the short-term outside financing will be set at a higher amount than if the payment were delayed until the next quarter. Since such daily events cannot

Assets	Liabilities
circulating assets - liquid assets - receivables - stock of construction materials - production not yet settled fixed assets - performance bond - stock of machines - remaining fixed assets	outside financing - short-term - long-term accumulated profits

Figure 2 : Simplified balance sheet of a construction syndicate

be foreseen, the amount of the circulating assets and short-term outside financing will be set off against each other. The result of this operation is the so-called "net working capital". In contrast to the former items the net working capital develops in quite a stable manner and for this reason is more suitable for budgeting. Figure 3 shows now the variables of the calculated balance sheet for the second step. The corresponding statements of income and of source and application of funds will be obtained from corresponding intermediate results.

Assets	Liabilities
net working capital	long-term outside financing
performance bond	accumulated profits
stock of machines	
remaining fixed assets	

Figure 3 : Calculated balance sheet

Tables 2a, 2b and 2c show part of a full financial budget for a section of a Swiss highway currently under construction.

Table 2a : Calculated balance sheet (SFr.)

	Apr:Jun 1977	Jul:Sep 1977	Oct:Dec 1977	Jan:Mar 1978
Assets				
net working capital	-102'424	- 91'260	-332'827	-247'865
performance bond	57'394	152'396	268'759	347'985
stock of machines	102'695	166'735	226'930	260'423
remaining fixed assets	42'750	40'500	99'050	93'600
	100'415	268'371	261'912	454'143
Liabilities				
long-term outside financing	29'844	64'645	94'440	122'970
accumulated profits	70'571	203'726	167'472	331'172
	100'415	268'371	261'912	454'143

Table 2b : Calculated statement of profits and losses (SFr.)

	Apr:Jun 1977	Jul:Sep 1977	Oct:Dec 1977	Jan:Mar 1978
Expenditures				
wages and social contributions	263'986	393'921	497'158	374'587
materials	113'407	433'802	878'128	668'296
energy	32'027	40'579	34'498	32'939
rental payments	149'218	174'007	148'974	142'652
payments to members of the partnership	31'498		115'997	
subcontractors	455'014	735'214	572'260	193'215
turnover tax	33'748		124'283	
deprecations	7'655	11'310	18'155	20'587
interest payments	5'226	5'703	9'731	8'130
remaining expenditures	19'969	29'345	34'148	27'950
	1'111'747	1'823'884	2'433'330	1'468'354
Revenues				
production	1'182'318	1'957'040	2'397'076	1'632'055
interest revenues				
valuation gains				
profit	70'571	133'155	-36'254	163'700

The estimation of all the variables given in Tables 2a, 2b and 2c requires a mathematical formulation of many relations arising from the rules of book-keeping, from law and from contracts. Fully extended, a piece by piece linear and step by step soluble equation system is obtained. It can be solved by the use of the IBM programming system CALL AS.

Table 2c : Calculated statement of source and application of funds (SFr.)

	Apr:Jun 1977	Jul:Sep 1977	Oct:Dec 1977	Jan:Mar 1978
Source of funds				
cash flow	50'676	84'264	-104'667	133'592
liquidations of fixed assets				
	50'676	84'264	-104'667	133'592
Application of funds				
investment	153'100	73'100	136'900	48'630
variation of net working capital	-102'424	11'165	-241'568	84'962
	50'676	84'264	-104'667	133'592

The following example illustrates the principal procedure. Let us assume that 2.8 % of the production turnover is to be paid to the members of the partnership for technical and economic consulting. If in a quarterly budgeting system a half year settlement of these amounts is arranged the following equation is obtained:

$$PETA_{t-1,t} = Dl_t * 0.028 * (T_{t-2,t-1} + T_{t-1,t})$$

The abbreviations are defined as follows:

$PETA_{t-1,t}$ = payments for economic and technical consulting within a period defined by the points of time t-1 and t.

$$Dl_t = \begin{cases} 1 \text{ if } t = 2,4,6, \text{ etc.} \\ 0 \text{ if } t = 1,3,5, \text{ etc.} \end{cases}$$

Dl produces non-linearity and ensures that the corresponding amounts are paid every second quarter only.

$T_{t-2,t-1}$ = turnover within a period defined by the points of time t-2 and t-1.

$T_{t-1,t}$ = turnover within a period defined by the point of time t-1 and t.

3. APPLICATION OF THE MODEL

3.1 Application of the results of the first budgeting step

Table 1 shows the results of the first budgeting step. The corresponding time series in this table can now be utilized systematically for construction management problems.

Material purchase:
In Table 1, time series for all the major engineering materials can be found (e.g. concrete, reinforcement steel, bituminous binders, gravel, plastics, etc.). These time series offer an excellent foundation for a useful purchasing policy with respect to the current economic situation. Let us assume a booming economy accompanied by high material prices. In negotiations with material suppliers it would in this case be useful to favour short-term contracts. Since the consumption material is known as a time series, the corresponding section of time can immediately be determined. Since a full economic cycle lasts from 6 to 8 years, one will tend to enter into supply contracts in which the quantity to be delivered is defined in a manner that allows renewal of the contract after about 3 years. Particular importance can be attached to the material time series in regard to construction activity in underdeveloped countries. It is well known that in these countries traffic and administrative confusions create serious hindrances to the punctual delivery of material. If, however, the future periodical material demand is known, one can insist on the delivery personally and in good time and thus contribute towards smooth progress of the construction project.

Subcontractors:
The same problem generally exists with the delegation of performance items to subcontractors. If the production to be done by subcontractors is known as time series an economically motivated delegation policy can be formulated.

Staff planning:
In Table 1 a time series for working hours can be found. This time series can be used to predict the necessary staff on the construction site in the course of time. Staff peaks can years in advance be recognized.

Machine use:
The time series for the operating hours of different machines provide an excellent foundation for planning the machine use. Moreover the long-term demand for specialists can be calculated.

Investment decisions:
The time series for the operating hours of machines can also be used to work out precise criteria with respect to machine investment. Let us assume that for a certain type the purchase price, service life, rent, etc. are known. Let us further assume the following three investment alternatives: purchase of all necessary machines, leasing of all necessary machines, leasing and purchase combined. If for the three investment alternatives the present discounted value is calculated, excellent information is obtained for making the decision in question.

Capacity analysis:
A construction site can be unterstood as a temporarily erected mill and thus all capacity problems connected with the operation of an ordinary manufacturing plant

arise. The time series in Table 1, representing the use of production factors, offer new possibilities of systematically analysing the stream of production factors with respect to capacity. Let us consider the following examples:

1. A site is located in the center of a big city. Since no space is left for a concrete mixer, it is planned to use ready-mixed concrete from a nearby ready-mixed concrete plant. From the time series for concrete consumption it can be seen that the maximum quarterly consumption occurs within the 4th quarter. From a capacity analysis, however, it can be seen that the possible crane capacity on this site is far from sufficient to meet the demand for crane operating hours in this quarter. It follows that the construction schedule has to be modified.

2. Let us assume a site located in an underdeveloped country. Since the local supply of materials is insufficient, it is planned to import the major materials. Materials are therefore shipped to the local transshipment port and from there hauled to the site. A capacity analysis shows, however, that the available transshipment capacity during half the performance time is absolutely insufficient.

Though until now emphasis has been given to the final results of the first budgeting step, the corresponding intermediate results are applicable as well. As soon as the estimation of the matrix of performance items and production factors is terminated, the corresponding column sums are calculated. The resulting row vector is identical to a column vector obtained by calculating the row sums in Table 1. The digits of this vector can be used for rough profit estimations, investment analysis, etc. The great advantage of these digits lies in the fact that they exist immediately after cost accounting is terminated. These digits thus can already be used in basic negotiations with the owner, the subcontractors and the material suppliers. Another sort of application, no less significant, lies in the estimation of the matrix of performance items and performance time. Since this requires an intensive study of the construction schedule and the construction drawings an ideal preparation of the construction management for its coming task is achieved.

3.2 Application of the results of the second budgeting step

Until now the model has been utilized more or less for pure construction management. Moving to the second budgeting step, one enters into financial management. The most important result of the second step is doubtless the time series for the net working capital. Under some plausible assumptions concerning the stock of receivables, the stock of credit items(1), the stock of materials and the stock of production not yet settled from this time series a corresponding time series of the liquid assets can be calculated. Represented graphically, a curve similar to Figure 4 will normally be obtained. This curve can be utilized for different problems in financial management. The greatest negative ordinate B represents the greatest amount of bank credit ever used during performance time, whereas the section T on the horizontal axis gives the period during which such credits are needed. The sections F_1 and F_2 on the vertical and T_1 and T_2 on the horizontal axis respectively

(1) bank credits not included

show possibilities of entering into time credit contracts, which in general have lower interest rates than demand credits. Reflux of cash begins where the curve passes the horizontal axis. From the shape of the curve it can be seen at what time and to what extent excessive buying power can be drained off. This offers a possibility of planning reinvestment of these amounts far in advance.

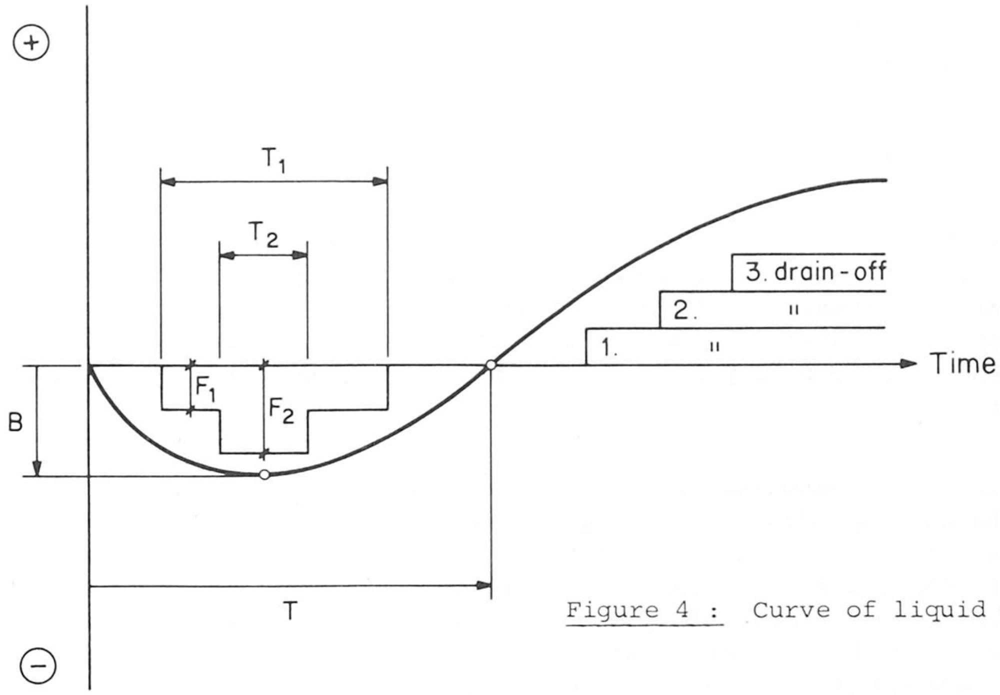

Figure 4 : Curve of liquid assets

Particular importance must be attached to the results of the second budgeting step in foreign business. With some additional equations, necessary foreign exchange operations can be determined. Thus controlled terminal exchange operations are possible, whereby currency risks are considerably reduced.

Due to computer application, the equation-system for obtaining the financial budget can be solved many times at low costs. The sensitivity of the system can thus be tested systematically. A particular exogenous variable (e.g. the exchange rate) is therefore changed marginally and the financial budget calculated a second time. From a comparison of the original and the new result a measure of the system's sensitivity on this particular variable is obtained.

4. CONCLUSIONS

This paper describes a method for construction management and is therefore an attempt to base the solution of the respective problems on a clear methodology. Two aspects must thereby be observed:

1. The systematic and complete treatment of the performance list, the cost accounting and the construction schedule.

2. The quantitative registration of future events on the construction site and the derivation of the corresponding financial consequences.

Todays large construction projects are often so complex that a single person cannot manage to keep a check on the technical and financial aspects of the projects. An instrument for communication between the different management levels is necessary. The model presented here meets these necessities.