# 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 perfor- mance list, whereas the columns are labelled with time periods. According to the construction schedule the performance time of every item is estimated and distri- buted 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, ope- ration 2 is quite a difficult task. It can be shown, however, that many items with- in 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 calcula- ted. 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 trans- pose of [MIP] by [MIT]. The result of this simple matrix multiplication will be an- other 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 | m² | | 5.3 | 8.8 | | 0.27 | 1.24 | 2.82 | 2.82 | 2.82 | 2.82 | 1.32 |

| | 1st quarter | 2nd quarter | 3rd quarter | 4th quarter | 5th quarter | 6th quarter | 7th quarter | 8th quarter |
|---|---|---|---|---|---|---|---|---|
| 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 | O | O | O | 18'283 | 18'283 | O |
| 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 | O | 51'543 | 41'904 |
| " transports | SFr | 362'816 | 575'769 | 384'o27 | 113'575 | 234'032 | 218'521 |
| " reinf.steel laying | SFr | O | 13'182 | 60'766 | 38'544 | 76'955 | 87'667 |
| " prestressing | SFr | O | O | O | O | O | O |
| " 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 | O | O | O | 2'350 | 2'803 | 3'415 |
| " edging | SFr | O | 62 | O | O | 8'445 | 8'781 |
| " pavements | SFr | 785 | O | 265 | 1'315 | 14'074 | 24'723 |
| " isolation work | SFr | O | O | 32'345 | 11'933 | 116'493 | 48'361 |
| " prefabrications | SFr | O | O | O | O | O | O |
| " sanitary work | SFr | O | O | O | O | O | O |
| working hours | h | 15'197 | 22'677 | 26'509 | 21'564 | 35'136 | 34'461 |
| operating hours building crane | h | O | 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 | O | O | O | O | 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 | O | O | 874 | 875 | O | O |
| " 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 | O | 4'720 | 4'720 | 4'720 | 9'440 | 9'440 |
| " " hot-air equipment | SFr | O | O | 4'067 | 4'068 | O | O |
| " " 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<br><br>  - liquid assets<br>  - receivables<br>  - stock of construction<br>    materials<br>  - production not yet<br>    settled<br><br>fixed assets<br><br>  - performance bond<br>  - stock of machines<br>  - remaining fixed assets | outside financing<br><br>  - short-term<br>  - long-term<br><br>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 de-
velops 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<br>performance bond<br>stock of machines<br>remaining fixed assets | long-term outside financing<br>accumulated profits |

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<br>1977 | Jul:Sep<br>1977 | Oct:Dec<br>1977 | Jan:Mar<br>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<br>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 con-tributions | 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 mathe-matical 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 pro-gramming 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 se-
ries 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 res-
pect 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 deter-
mined. 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 un-
derdeveloped countries. It is well known that in these countries traffic and ad-
ministrative confusions create serious hindrances to the punctual delivery of ma-
terial. If, however, the future periodical material demand is known, one can in-
sist 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 sub-
contractors. 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 specia-
lists 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 cer-
tain type the purchase price, service life, rent, etc. are known. Let us further
assume the following three investment alternatives: purchase of all necessary ma-
chines, leasing of all necessary machines, leasing and purchase combined. If for
the three investment alternatives the present discounted value is calculated, ex-
cellent 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, of-
fer 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 con-
   crete 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. Ma-
   terials 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 insuffi-
   cient.

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 ne-
gotiations 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 wor-
king 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 sec-
tions $F_1$ and $F_2$ on the vertical and $T_1$ and $T_2$ on the horizontal axis respectively

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[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.
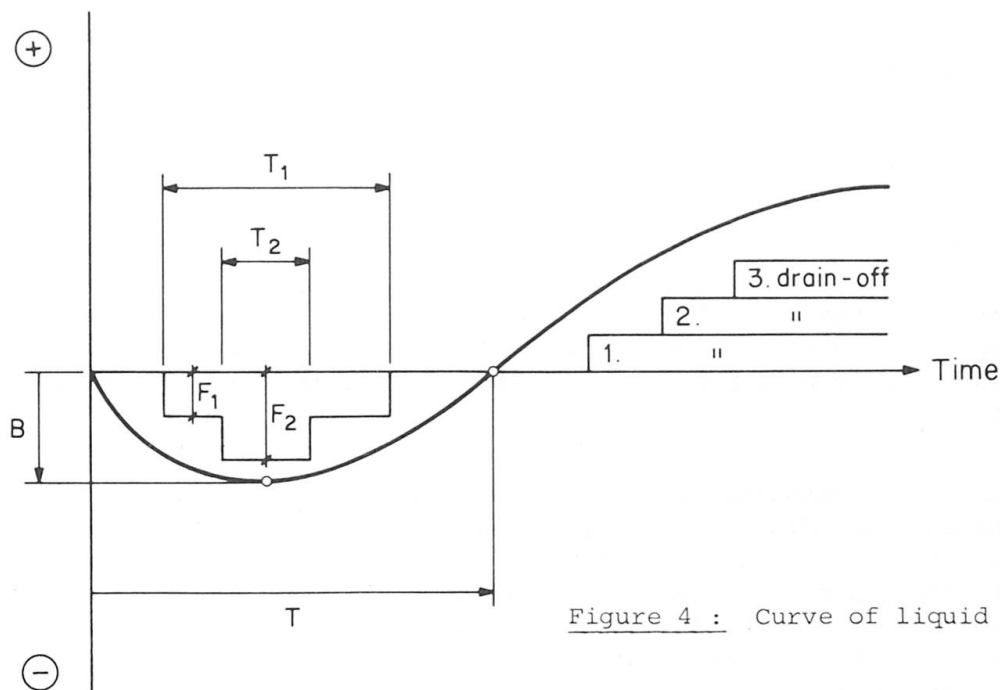


Figure 4 :   Curve of liquid assets

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.