Method of Forecasting Payments on Construction Contracts

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ABSTRACT

The research on forecasting techniques for payments on current and proposed construction contracts reported in this paper was performed as part of a study to develop a system for generating a 1-to-2-year forecast of monthly cash flows for the Virginia Department of Highways and Transportation. The study revealed that presently used cash flow forecasting methods consistently underestimate ending cash balances. In addition, it showed that the behavior of individual contracts varies widely, with the percent paid out at the halfway point in the schedule ranging from zero to 93 percent. Furthermore, contractors' schedules, on which current forecasts are based, are not reliable indicators of contract duration, payout patterns, or final cost. By the end of the scheduled duration (contractual time limit not allowing for shutdowns) contracts are typically less than 70 percent complete. Cost overruns average 7.8 percent of the contract amount. Seasonality is a critical determinant of construction payout, as is exhibited by the fact that payouts can be six times as high in September as in January. A simple technique that emphasizes the effects of seasonality on payout and realistic estimates of contract duration explained more than 93 percent of the variation in a retrospective test of a sample data base. The accuracy of the forecasting method in actual use will depend on the variability of the weather and on the prompt entry of information on contracts let and scheduled advertisement dates into the forecasting data base.

During the past several years revenues for most highway departments have become volatile and unpredictable, and construction expenditures have been subjected to unprecedented rates of inflation. During such periods an agency runs a serious risk of encountering an inadequate cash balance in carrying out its construction and maintenance program. This risk can be minimized by (a) maintaining large cash balances that divert funds from current needs or (b) developing and using reliable management tools for short-term forecasting and monitoring of cash inflows and outflows. In Virginia the latter approach has been the chosen course of action, and in this paper one phase of improving the current forecasting technique--a more reliable construction payout model--is described.

Improved techniques for forecasting revenues, federal-aid reimbursements, and other cash flow components are beyond the scope of the paper, although research to improve these aspects of the forecasting techniques is being conducted. In this paper the data required to derive the construction contract monthly payout forecast are discussed, the techniques currently used in Virginia are critiqued, a new forecasting technique is explained, and, finally, a test of the technique is presented.

CASH FLOW FORECASTING IN OTHER STATES

States that have systematic cash forecasting methods, or are developing them, include Alabama, Arkansas, Pennsylvania, New York, Florida, Iowa, California, Utah, and Idaho. The project team reviewed in detail the methods that have been developed in Pennsylvania, New York, and Florida and concluded that the forecasting techniques in use in New York held the most potential as a basis for developing a forecasting method for use in Virginia. These techniques are described hereafter in the section on the monthly factors model.

In addition to details on forecasting techniques, the project team gained two significant insights from analyzing the forecasting systems in these states. The first is that a technically accurate forecasting technique, although vital to success, is not sufficient to generate good forecasts if the information system employed does not provide to the forecasting system a steady flow of up-to-date, accurate, and easily accessible data. The second insight is that an accurate cash flow forecasting system can be a useful management tool only if the forecasting function is closely integrated with the programming function, because programming changes must be promptly reflected in the forecasts and forecasted cash flow surpluses or shortfalls must be properly taken into account in programming decisions.

DATA COLLECTION AND PROFILE

Data were collected on 173 contracts that began after July 1, 1979, and were completed by August 1982. The payment data were plotted by computer against elapsed time for each contract, and these plots were compared to identify and exclude from the analysis contracts that exhibited unusual payout patterns. After exclusion of the outliers, the sample consisted of 162 contracts representing 19.5 percent of the construction activity during fiscal 1980, 27.4 percent during fiscal 1981, and 9 percent during fiscal 1982. The distribution of contracts by contract amount and duration given in Table 1 indicates that half of the sample consisted of contracts of $500,000 or less and 12 months or less in duration and that 9 percent were greater than $2,500,000 and longer than 1 year. Contracts from $500,000 to $2,500,000 and from 1 to 2 years in length made up 23 percent of the sample, or 37 contracts. This mix of large and small, short and long contracts is representative of the total work program of the Virginia Department of Highways and Transportation. The distribution of the dollar volume of construction activity by size of contract (Table 2) reveals that the 14 largest contracts accounted for over 50 percent of the dollar volume of construction activity for the sample and that the 92 smallest contracts

TABLE 1 Distribution of Sample by Duration and Contract Amount

Contract Amount ($)	Actual Duration from Contract to Completion (months) 0-3	4-6	7-12	13-17	18-24	25-36	Total
<250,000	11	18	15	1	0	0	45
250,001 to 500,000	1	3	33	9	1	0	47
500,001 to 1,000,000	0	1	15	15	2	0	33
1,000,001 to 2,500,000	0	1	1	12	8	1	23
2,500,001 to 6,000,000	0	0	0	2	1	5	8
>6,000,000	0	0	0	0	5	1	6
Total	12	23	64	39	17	7	162

TABLE 2 Distribution of Construction Dollar Volume by Size of Contract

Contract Amount ($)	No. of Contracts	Percentage of Dollar Volume	Cumulative Percentage
<250,000	45	3.3	3.3
250,001 to 500,000	47	9.9	13.2
500,001 to 1,000,000	33	13.2	26.5
1,000,001 to 2,500,000	23	23.4	49.8
2,500,001 to 6,000,000	8	18.6	68.5
>6,000,000	31.5	100.0	

made up about 13 percent of the volume. The average contract duration from contract date to completion, weighted by the dollar volume, is 18.4 months, and 80 percent of the contracts were for combination construction or combination plus bridge construction. The distribution of contracts by road system and project type given in Table 3 shows that 146 of the 162 contracts were on the primary and secondary highway systems and, of these, all but 6 involved combination or bridge construction or both. Of the 13 Interstate contracts, 9 were for combination or bridge construction or both. The sample included only 3 urban projects.

TABLE 3 Distribution of Sample by Road System and Project Type

Project Type	Road System Interstate	Primary	Secondary	Urban	Total
Combination or minimal plan	2	46	41	2	91
Combination with bridge	3	19	15	1	38
Bridge	4	5	14	0	23
Grading	0	2	0	0	2
Paving	1	3	0	0	4
Landscaping	1	1	0	0	2
Signals	2	0	0	0	2
Total	13	76	70	3	162

The payout data show that the behavior of individual contracts was highly variable. For example, the ratio of actual duration to scheduled duration varied from less than one to six; the number of months between the contract date and the first payment can be anywhere from zero to 13; and the final amount paid the contractor can vary from 84 percent to 165 percent of the stated contract amount. This variability is illustrated in Figure 1, which shows the minimum, maximum, and mean payout by contract size group at 50 percent of time elapsed from contract date to completion date. Interestingly, the largest contracts, those greater than $6 million,

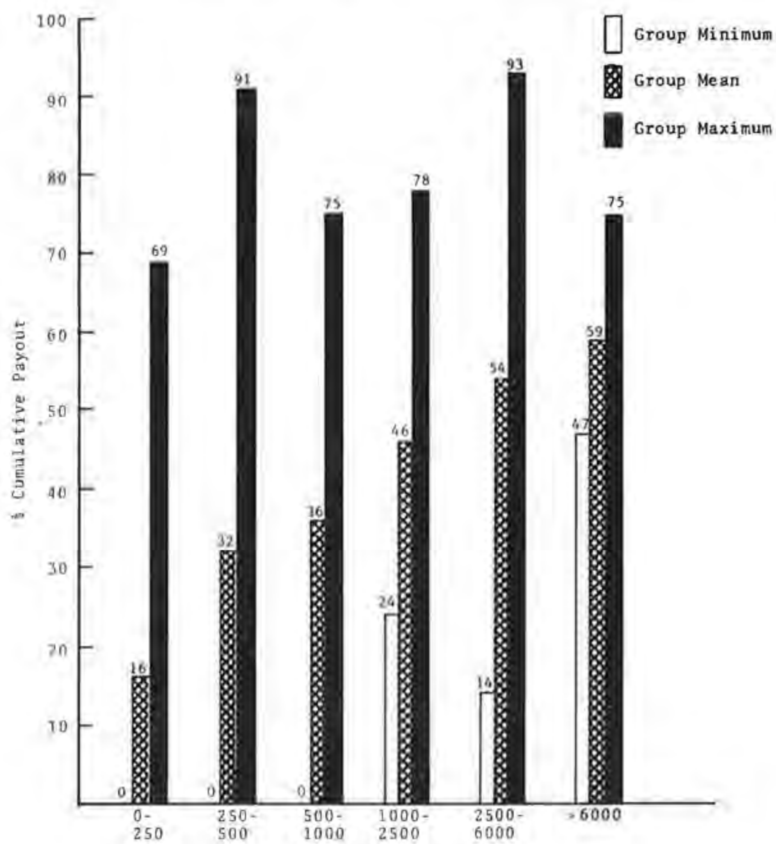

FIGURE 1 Percent paid out at 50 percent time elapsed, by contract size.

were the least variable, ranging from 47 to 75 percent payout at 50 percent elapsed time. However, the next to largest category of contracts, $2.5 to $6 million, was among the most variable, ranging from 14 to 93 percent, and for the three smallest contract size groups, the minimum payout at 50 percent elapsed time was zero and the maximum 91 percent.

Despite the variability of individual contracts, predictable patterns were found. The pattern shown in Figure 2 is that longer duration contracts paid out more rapidly at any point in the life of the contract than did shorter duration contracts. For example, at 50 percent time elapsed, a 7-to-12-month contract was 29 percent paid out, on the average, but a 25-to-36-month contract was 60 percent paid out. In general, the percent paid out was likely to be closer to the percent time elapsed on long duration contracts than on short contracts. The data also show that large contracts had smaller cost overruns, in percentage terms, than smaller contracts. Large contracts also tended to stay closer to schedule than smaller contracts.

CURRENT FORECASTING TECHNIQUES

Current Contracts

The techniques currently used by the department to forecast construction contract payout have certain identifiable limitations. In the case of current contracts, the forecast is based on the contractor's progress schedule estimate. If the cumulative payout is not equal to the scheduled payout, the difference is distributed equally over the months remaining on the progress schedule. If the project is not completed on time, the balance remaining in the contract, if less than $100,000, is paid out in the following month and, if greater than $100,000, over the following 6 months.

The difficulty with this forecasting technique is that the data show that contractors' progress schedules were not reliable indicators of the actual duration of contracts, final cost, or payout patterns. Contractors' schedules typically did not allow for any delays in construction, particularly seasonal slowdowns and shutdowns. This finding is illustrated by Figure 3, which shows the ratio of actual to scheduled payout throughout the scheduled time period for contracts of various sizes. As a general rule, contracts fell further and further behind as they approached the end of the scheduled time limit. For example, contracts in amounts from $1 million to $2.5 million were nearly on schedule at the 25 percent time elapsed point, but by the 75 percent time elapsed point they had fallen to 72 percent of the scheduled estimate. By the time the projects were scheduled for completion only 64 percent of the work had been done and paid for. The largest projects, those over $6 million, generally stayed closer to schedule than smaller projects, but they also fell behind as time elapsed, until they were only 87 percent completed when the scheduled time limit was reached.

Table 4 gives the extent to which schedules were exceeded on contracts of various sizes. The number of additional months needed ranged from 5 to 25, with a dollar-volume-weighted average of 14.5 months, or 82 percent of scheduled duration. The final cost of a project was generally much closer to the original contract than was duration. The cost

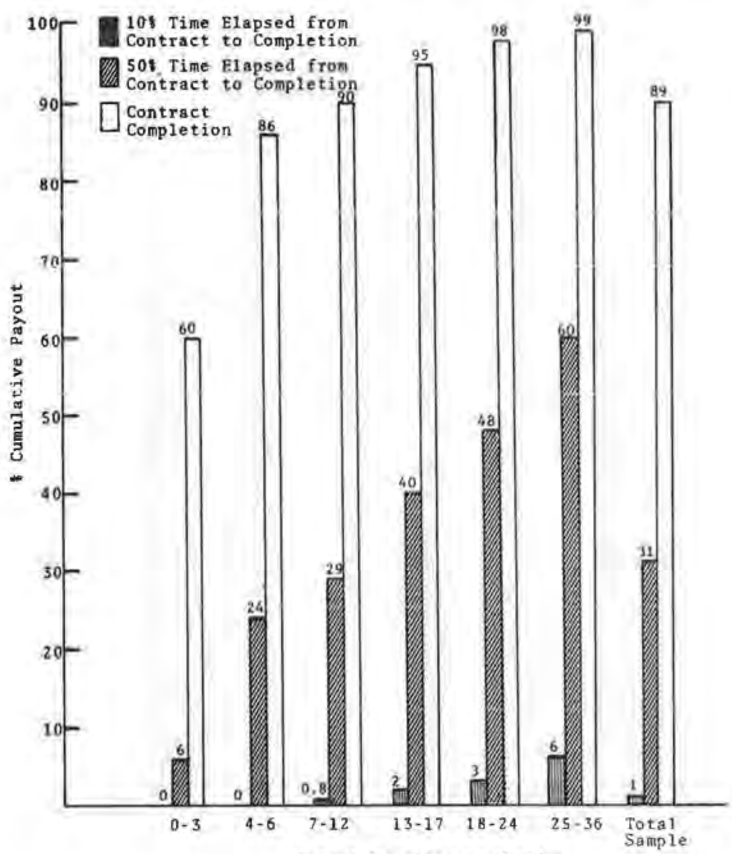

FIGURE 2 Mean payouts at three points in contract, by contract duration.

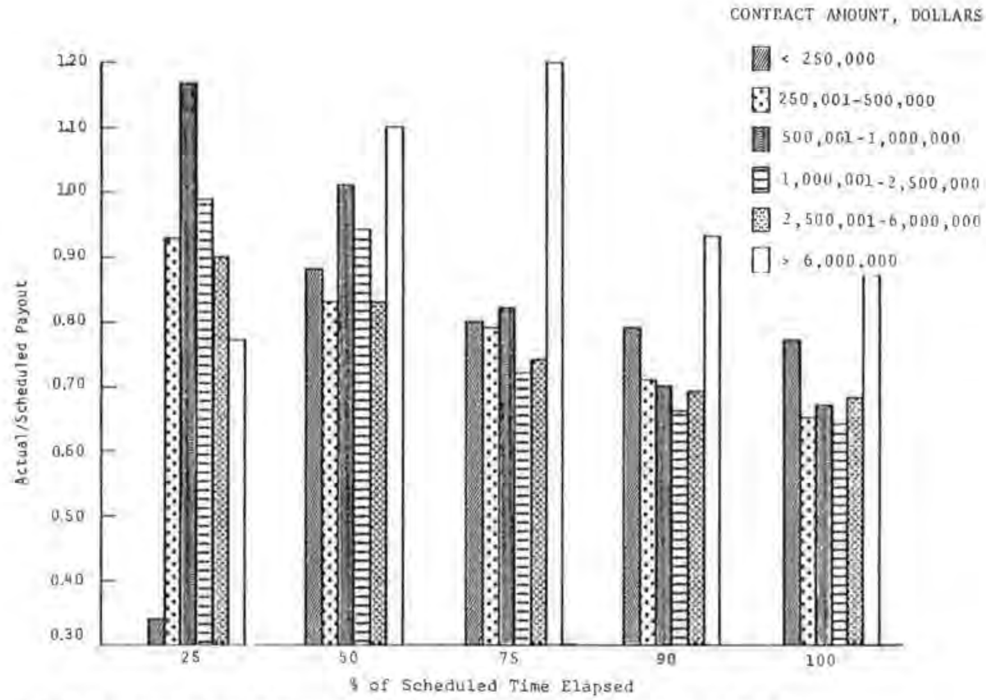

FIGURE 3 Actual/scheduled payout versus time elapsed on contractors' schedules.

TABLE 4 Schedule Overruns by Contract Size

Contract Size ($)	Actual Duration/ Scheduled Duration	Additional Months Needed
<250,000	1.83	5.0
250,001 to 500,000	1.88	8.8
500,001 to 1,000,000	1.88	10.9
1,000,001 to 2,500,000	2.10	18.0
2,500,001 to 6,000,000	2.08	25.0
>6,000,000	1.44	10.0
Weighted average	1.82	14.5

overruns ranged from 2.7 to 11.6 percent, with contracts exceeding $6 million having the smallest percentage overruns. The weighted average for the sample was 7.8 percent. The current forecasting technique takes into account only a small portion of these overruns. Work orders received on a contract through the date of the forecast are added to the original contract amount for a revised contract total. Future payments are projected until the sum of payments is equal to the revised contract total. When this point is reached in the forecast, no further payments are projected. This method makes no attempt to forecast work orders not received at the time the forecast is made. Furthermore, work orders account for only 28 percent, on the average, of cost overruns; the remaining 72 percent consists of quantity overruns, which do not require work orders.

For example, on one contract, work orders received by July 1980 amounted to $29,000, for a revised contract total of $5,090,000. A forecast made in that month, therefore, would have projected payments totaling $5,090,000. However, work orders totaling another $70,000 were subsequently received for a revised contract total of $5,160,000. In addition, the final sum of payments actually made came to $5,303,000. The total cost overrun was actually $242,000, of which only $99,000 was accounted for by work orders.

The following is a summary of the limitations of the current forecasting techniques for ongoing contracts.

1. Over-reliance on contractors' progress schedule estimates, which are not good indicators of actual payments made and which tend to ignore the seasonality of construction;
2. Failure to make reasonable estimates of the actual duration of contracts; and
3. Failure to anticipate probable cost overruns, which range from 2.7 to 11.6 percent of the contract amount.

Proposed Contracts

The forecasting technique used for payouts on proposed contracts also has shortcomings. The 23-month-payout forecasting schedule assumed for all proposed contracts is given in Table 5. When this schedule is plotted, it becomes a smooth curve as shown in Figure 4.

TABLE 5 Twenty-Three-Month Payout Schedule for Proposed Contracts

Month	Monthly Payout (%)	Cumulative Payout (%)	Month	Monthly Payout (%)	Cumulative Payout (%)
1	0.6	0.6	13	4.0	79.6
2	3.7	4.3	14	4.2	83.8
3	7.0	11.3	15	3.7	87.5
4	9.2	20.5	16	1.6	89.1
5	6.9	27.4	17	2.8	91.9
6	6.9	34.3	18	1.6	93.5
7	7.0	41.3	19	2.2	95.7
8	6.7	48.0	20	1.0	96.7
9	7.2	55.2	21	1.1	97.8
10	7.8	63.0	22	1.5	99.3
11	5.6	68.6	23	0.7	100.0
12	7.0	75.6			

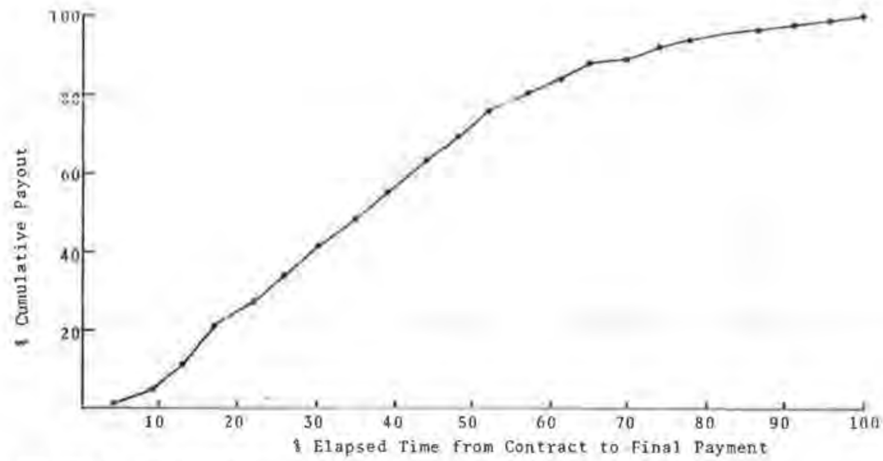

FIGURE 4 Twenty-three-month payout curve used for proposed contracts.

The principal weakness of this 23-month forecasting technique, aside from the failure to anticipate cost overruns, is that it does not allow for the seasonality of construction work. The importance of seasonality is shown in Figure 5, which shows monthly construction payout during fiscal year 1982 as a percentage of the total for the year. As may be expected, the peak period for construction activity was summer and autumn, and the slow season was the middle of winter (January and February). The monthly percentage for the peak month of September was more than six times the percentage for the slowest month of January, and the effect of seasonality naturally varied from year to year. This variability, as well as the role of seasonality in forecasting, will be discussed in greater detail later.

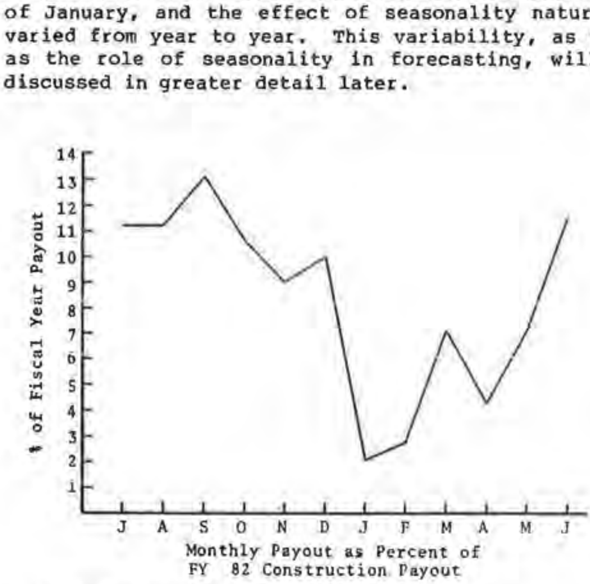

FIGURE 5 Seasonality of construction payout.

Forecasting Results

The final result of these forecasting limitations is an unsatisfactory forecast. This is illustrated by a comparison of actual construction payouts from April 1982 to March 1983 with a forecast made by the budget division in April 1982 using the techniques described previously. The most striking feature of this comparison is that the forecast seriously underestimated the summer and autumn construction peak and underestimated payout more than three times as often as it overestimated payout, because the technique fails to consider seasonality. The difficulty of predicting the advertisement dates of proposed projects may also have affected the forecast. Until recently, these advertisement dates were quite uncertain and neither the information in the computerized project development monitoring system (PDMS) nor the 2-year advertising schedule was reliable as a forecasting input.

The programming and scheduling division recently completed an analysis of the advertising schedule released in October 1982, and the reliability of the schedule was found to have greatly improved--of the 179 projects scheduled for advertisement from October 1982 through March 1983, 159 were advertised. Of these, 127 were advertised in the month scheduled and another 28 were advertised within the same quarter. In addition, 14 projects were advertised that had been advanced or added to the schedule, and 6 projects were dropped from the schedule. Variability in advertisement dates is normal in department operations and will limit the accuracy of any forecasting technique. Nevertheless, this limitation can be significantly offset by timely updates of the forecasting data base whenever the advertisement schedule is changed.

DEVELOPMENT OF NEW FORECASTING TECHNIQUES

The problem of forecasting payouts on construction contracts relates to the following factors, each of which will be discussed separately: (a) contract duration, (b) the final amount paid the contractor (known as the final estimate), (c) payout patterns, and (d) advertisement dates for proposed contracts.

Contract Duration

Contract duration is defined, for the purposes of this paper, as actual elapsed time in months from the month in which the first payment is made to the month in which work is completed. Intuitively, contract size would be expected to be the single most powerful determinant of duration, and an analysis of the data has shown this to be correct although the relationship is not strictly proportional. Other factors that may influence contract duration are project type, road system, and the month in which the contract is signed.

A regression analysis was performed on these factors. The results of the analysis showed that 69 percent of the variation in duration was explained by contract size but that the increases in duration were less than proportional to the increases in size, especially for the largest contracts. The results also showed that contracts took less time to complete on the secondary system than on the other systems, and less time to complete if the contract was signed in January, February, March, April, July, or December. Contracts took longer to complete if they were combination construction projects involving bridges or if they were signal projects. An equation that includes all of these variables can explain 76 percent of the variation in contract duration. This equation is

$$ACTDUR = -38.78 + 3.84 \ln NETAMT - 3.28\ MNCN - 0.49\ RDSYS + 1.53\ PRTYPE$$

where

- ACTDUR = duration in months from month of first payment to month of completion;
- NETAMT = original contract amount;
- MNCN = month in which contract is signed (1 if January, February, March, April, July, or December, otherwise 0);
- RDSYS = road system (1 if secondary, otherwise 0); and
- PRTYPE = project type (1 if project is a combination contract with a bridge involved or a signal project, otherwise 0).

Table 6 gives the durations calculated for contracts of various sizes and categories using this regression equation. For a given contract size, the contracts with the longest estimated durations were combination construction plus bridge or signal contracts on the Interstate, primary, or urban systems and were signed in May, June, or August through November. Contracts with the shortest estimated durations were those other than combination plus bridge or signal projects on the secondary system signed in January through April, July, or December. The difference between the shortest and longest duration estimated for contracts of a given size was 5.5 months.

Amount of the Final Estimate

As discussed in a previous section, final estimates (the amount paid the contractor) ranged from 102.7 to 111.6 percent of the original contract amount. For forecasting purposes, the mean percentage cost overrun for each contract size group was used to predict the size of the final estimate for each contract:

Final estimate = Cost overrun factor x contract amount where cost overrun factors are

Cost Overrun Factor	Contract Size ($)
1.090	<250,000
1.078	250,001 to 500,000
1.116	500,001 to 1,000,000
1.094	1,000,001 to 2,500,000
1.115	2,500,001 to 6,000,000
1.027	>6,000,000

Payout Patterns

The timing, number, and size of the monthly payments on a construction contract constitute the payout pattern. The payout patterns of the sample contracts were analyzed by two methods. The first was multiple regression analysis and the second a method of monthly factors analysis that emphasizes seasonality and is a modification of the method used by the New York State Department of Transportation (NYSDOT).

Regression Analysis

A regression analysis was performed for each contract size group in Table 2. The cumulative percent paid out in each month in the life of each contract was analyzed as a function of the percentage of time elapsed from the first payment to the completion date, the month in which the payment was made, and the cumulative percent already paid out. The regression equation includes the square and the cube of the percentage of time elapsed (PCTT), and in this polynomial form allows for changes in the slope of the payout curve. The variable PMTMON accounts for the fact that construction activity is much lower in winter and early spring than in the rest of the year.

$$PCTP_t = a + b(PCTT) + c(PCTT^2) + d(PCTT^3) + e(PCTP_{t-1}) + f(PMTMON)$$

where

- $PCTP_t$ = cumulative percentage of final estimate that is paid out by the end of month t;
- PCTT = percentage of time elapsed over the period from the first payment through the month of completion;
- $PCTP_{t-1}$ = cumulative percentage that was paid out by the end of month t-1; and
- PMTMON = dummy variable representing the month in which the payment is made; the

TABLE 6 Contract Durations (months) Calculated by Regression Equation

	Secondary Highways				Interstate, Primary, and Urban Highways			
	Contract Month[a]				Contract Month[a]			
	1-4, 7, 12		5, 6, 8-11		1-4, 7, 12		5, 6, 8-11	
	Project Type[b]		Project Type[b]		Project Type[b]		Project Type[b]	
Contract Amount ($)	C+B or Signal	Other	C+B or Signal	Other	C+B or Signal	Other	C+B or Signal	Other
125,000	5.5	4.1	8.8	7.4	6.3	4.9	9.6	8.2
375,000	9.5	8.1	12.8	11.4	10.3	8.9	13.6	12.2
750,000	12.1	10.7	15.4	14.0	12.9	11.5	16.2	14.8
1,500,000	14.6	13.2	17.9	16.5	15.4	14.0	18.7	17.3
3,000,000	17.1	15.7	20.4	19.0	17.9	16.5	21.2	19.8
6,000,000	19.6	18.2	22.9	21.5	20.4	19.0	23.7	22.3
12,000,000	23.1	21.7	26.4	25.0	23.9	22.5	27.2	25.8

[a]Contract months are keyed consecutively; month 1 is January.
[b]C = combination contract; B = bridge contract.

dummy variable is 1 if the month is January, February, March, or April and 0 if the month is May, June, July, August, September, October, November, or December.

The results of the regression analysis were quite encouraging and the R^2s are given in Table 7 for each contract size group. Significance tests on the explanatory variables were acceptable at the 95 percent level of confidence. The results of a forecasting test of these equations will be presented in a later section.

TABLE 7 R-Squares for Payout Regressions

Contract Size ($)	R^2
<250,000	0.87
250,001 to 500,000	0.94
500,001 to 1,000,000	0.96
1,000,001 to 2,500,000	0.98
2,500,001 to 6,000,000	0.99
>6,000,000	0.99

Monthly Factors Analysis

A forecasting technique based on the duration of individual contracts and the seasonality of the total work program has been in use by the NYSDOT for several years. The basic equation is

$$ESTPMT_t = AMTREM_{t-1} \times (MONFACT_t / \Sigma_t^n MONFACT)$$

where

- $ESTPMT_t$ = estimated monthly payment for month t;
- AMTREM = amount remaining in the contract after the payment made in month t-1;
- $MONFACT_t$ = monthly seasonality factor for month t; and
- $\Sigma^n MONFACT$ = sum of monthly seasonality factors for the months remaining in the contract's duration from month t to month of final payment.

The monthly seasonality factors are computed from historical data by dividing the total construction contract payout for each month (for all contracts) by the total payout for the year. The result gives an estimate of the percentage of annual payout that typically occurs in each month. Then the monthly seasonality factors used for forecasting may be averaged over several years to smooth out year-to-year variations. The first step in adapting the monthly factors method to Virginia was to calculate the monthly seasonality factors for the Virginia Department of Highways and Transportation construction program. In order to determine the variability of these factors, they were calculated using four data bases: (a) monthly payouts for the total construction program for FY 1981, (b) monthly payouts for the total construction program for FY 1982, (c) FY 1981 payout for the sample data base described previously, and (d) total payout for the combined 3-year sample data base. The results are shown in Figure 6.

The fiscal 1981 sample showed the greatest difference between the peak month and the lowest month of the year: The July factor of 0.16 was more than eight times the March factor of 0.019. On the other hand, the seasonality was less extreme for the combined 3-year sample. The proportion of the total annual payout for the peak month of July was 0.12, about three times the proportion paid out for the lowest month, March, which was 0.036. The totals for fiscal years 1981 and 1982 exhibited intermediate levels of seasonality, with the most highly variable months being January, which ranged from 0.021 to 0.069, and March, which ranged from 0.019 to 0.071. The peak months of July and August were moderately variable. In contrast, the months of September and October were quite stable. This means that year-to-year variations in monthly seasonality could produce forecasting errors of several millions of dollars, particularly in January and March and in the peak months. Forecasting tests were conducted on the sample using monthly factors from the combined 3-year sample and from the fiscal 1981 sample. The results of these tests will be presented in the next section.

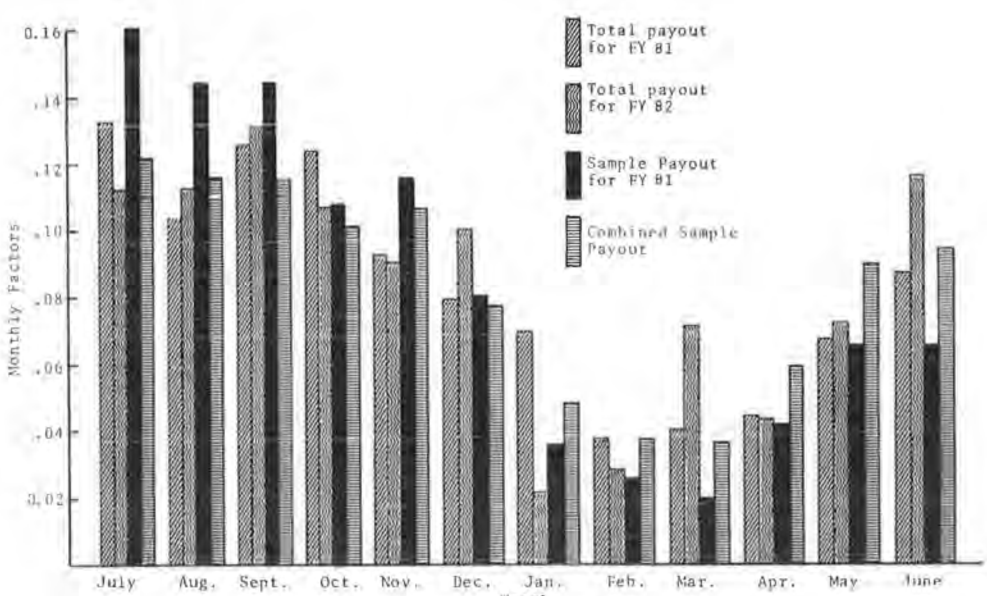

FIGURE 6 Variations in monthly factors from sample and aggregate payouts.

A number of trial calculations with the monthly factors equation indicated that it performs better empirically if certain assumptions are made about the timing and size of the first two payments as well as the final payment. Based on the data in the sample, the first payment is assumed to occur 1 month after the contract month if the estimated duration is less than 3 months, and 2 months after the contract month if the estimated duration is 3 months or longer. Using the sample data base, the sizes of the first, second, an final payment are specified as a percentage of the final estimate, depending on the contract size group. These percentages are given in Table 8. Next, the percentage of the contract that

TABLE 8 First, Second, and Final Payments as Percentage of Final Estimate

Contract Size ($)	First Payment	Second Payment	Final Payment
<250,000	14.5	23.8	6.5
250,001 to 500,000	8.2	12.0	3.7
500,001 to 1,000,000	5.5	10.4	2.6
1,000,001 to 2,500,000	5.0	6.1	1.0
2,500,001 to 6,000,000	4.7	5.6	0.5
>6,000,000	2.6	3.1	0.001

is paid out by the completion month was calculated from the sample by size of contract (Table 9). In addition, the payout pattern was constrained such that the payment percentage made in the month following completion equals [1 - (% paid by completion month + % last payment)], the next payment always equals zero, and the last payment is made 3 months after completion.

TABLE 9 Percentage Paid Out by Completion Month

Contract Size ($)	Percentage Paid Out
<250,000	86.9
250,001 to 500,000	88.6
500,001 to 1,000,000	93.9
1,000,001 to 2,500,000	96.5
2,500,001 to 6,000,000	97.3
>6,000,000	100.0

The following example illustrates how duration, final estimate, and monthly payments are calculated using the methods described. In this example

Project no. = 0641-016-150,
Project type = combination construction,
Road system = secondary,
Contract amount = $79,771,
Contract month = June,
Estimated duration = -38.37 + 3.84 (ln NETAMT) - 3.28 (MNCN) - 0.49 (RDSYS) + 1.53 (PRTYPE),
NETAMT = $79,771,
MNCN = 0 for June,
RDSYS = 1 for secondary,
PRTYPE = 0 for combination construction,
Duration = -38.37 + 3.84 (ln 79771) - 3.28 (0.0) - 0.49 + 1.53 (0.0) = 4.07 rounded to 4 months from first payment to the month of completion,
Final estimate = $79,771 x 1.090 = $86,950 (this adjusts for cost overruns), and

Monthly factor =		
	JAN .048	JULY .114
	FEB .037	AUG .118
	MAR .035	SEP .117
	APR .060	OCT .104
	MAY .094	NOV .106
	JUN .091	DEC .076.

Using the monthly factors shown, the following estimates of payout can be made (note that November is the estimated completion month).

Month	Payment ($)	Calculation
June	0	The model is constrained so that no payments are made in first two months after contract date
July	0	
Aug.	12,655	86950 x .145 (total payment times 1st payment proportion for contracts less than $250,000)
Sept.	20,721	86950 x .238 (total payment times 2nd payment proportion for contracts less than $250,000)
Oct.	20,891	[.104/(.104 + .106)] [(86950 x .869) - (12655 + 20721)]
Nov.	21,293	[.106/.106] [(86950 x .869) - 12655 + 20721 + 20891)]
Dec.	5,749	[86950 - (12655 + 20721 + 20891 + 21293)] - [86950 x .0649]
Jan.	0	Next-to-last payment always = 0
Feb.	5,643	86950 x .0649 (total payout times last payment %)

The calculation for the month of October, in greater detail, is

October monthly payment = (October monthly factor/Sum of factors for months remaining from October to completion month) x Amount remaining to be paid out by completion month.

In the foregoing calculation, the monthly factor is .104 for October, the sum of remaining factors to completion month is .104 for October + .106 for November, which equals .210. The total amount to be paid out by completion is $86,940 x .869 = $75,560, the amount already paid out = $12,655 + $20,721 = $33,376, the amount remaining to be paid out by completion = $75,560 - $33,376 = $42,184, and the monthly payment = (.104/.210) x $42,184 = $20,891.

The payout forecasts generated by the monthly factors method can be plotted as payout curves comparable to the standard curve shown in Figure 4. In general, the payout in the monthly factors curve is less accelerated than in the standard curve until near the end of the curve, and it is also less smooth than the standard curve, with dips and bulges that show the effects of seasonality. For example, from November to March the slope of the curve is less than it is from June to October, indicating a slower rate of payout. Of course, no forecasting technique or payout curve can possibly duplicate the highly variable behavior of individual contracts. Nevertheless, the forecasting tests described in the next section indicate that the monthly factors method can do a better job of duplicating the behavior of all contracts taken together than does the standard payout curve.

RETROSPECTIVE TESTS OF FORECASTING TECHNIQUES

The forecasting techniques described in the previous section were tested retrospectively to determine if they could duplicate the payout patterns of the sample. This was not a true forecasting test, however, for the following reasons: (a) a true forecasting test should be on contracts that were not in the sample used to develop the forecasting technique; (b) the retrospective tests did not involve predicting the advertisement dates for proposed contracts; and (c) the retrospective tests utilized monthly seasonality factors based on the actual sample data, whereas in actual forecasting one will always be trying to predict the next year's payout using monthly factors from the previous year or years. Such monitoring is under way.

Tests of Monthly Factors Method

A simplified version of the monthly factors method was tested using two sets of monthly factors. The simplified version of this method is designed to be simple to implement because it does not require updating each month based on the payments that have been made. When a contract has been added to the data base, no further information will be required, unless the contract is a proposed contract the estimated cost or advertisement date of which is changed.

The retrospective test using monthly factors from the combined 3-year sample was extremely successful. As Figure 7 shows, the forecast tracked the highs and lows of construction activity very closely. Statistically, the monthly factors method explained more than 93 percent of the variation in construction payout in this test. On the other hand, the method underestimated the construction peak in June through September of 1980 by several million dollars. This indicates the possibility that weather conditions were exceptionally good that summer, allowing the summer peak to be even higher than usual.

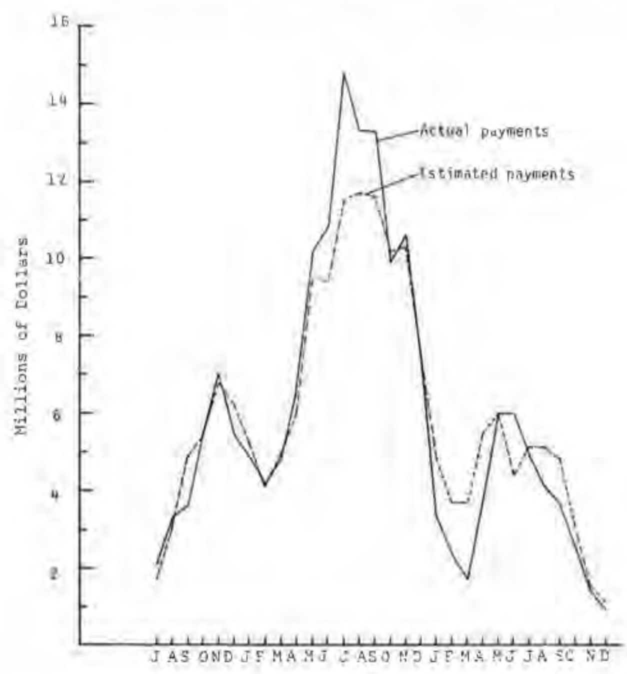

FIGURE 7 Test of simplified monthly factors method using factors from combined sample.

Another retrospective test was performed using monthly factors from only the fiscal 1981 portion of the sample to see if more specific monthly factors would improve the forecast. The estimates of the summer peak were much closer, but the rest of the forecast was not as good. Overall, the percentage of variation explained in this test was about 85. This result indicates that it is very difficult to improve one segment of the forecast by tailoring the monthly factors to it without adversely affecting the rest.

A more elaborate version of the monthly factors method was also tested. In this version, the data base was continually updated so that the amount remaining in each contract each month was calculated using the actual payments made up to that point. Surprisingly, the results of this test were not as good as those of the streamlined version.

Tests of Regression Method

The regression method described previously was also tested in both a simplified and an elaborate version. Both of these tests were significantly worse than the monthly factors method. The reason may be that the regression method does not capture the effects of seasonality as well as the monthly factors method. Furthermore, even though the R^2s were high, small percentage errors on large contracts resulted in relatively large absolute errors in terms of dollars per month.

IMPLEMENTATION REQUIREMENTS

The information and procedures required for implementation of the simplified version of the monthly factors method are relatively simple and the department is currently implementing the method as a comparison with the current forecasts. This forecasting method requires less new information each month than does the method now used for current contracts. For each contract, whether existing or proposed, six items of data are needed:

1. Project number,
2. Project type,
3. Road system,
4. Federal share (optional),
5. Contract amount or construction cost estimate, and
6. Contract date or advertisement date.

Implementation of the forecasting method will initially require a data base consisting of all projects that have been awarded, advertised, or scheduled for advertisement. After that, monthly updates will be required on (a) new contracts that have been awarded and (b) any changes in advertisement dates or construction estimates for projects on the advertising schedule.

The sample data base of completed contracts used to develop the forecasting method will be expanded to include all additional projects that have been completed since August 1982. These data will be reanalyzed to ensure that the equations for duration and final estimate and the monthly factors are representative of recent construction activity. This process of data collection and reanalysis will be repeated periodically.

CONCLUSION

Analysis has shown that aggregate payout on construction contracts can be adequately predicted given improved forecasting techniques and information management. The forecasting technique described in this paper requires information only on the type of construction, the road system, the size of the project, and its actual or prospective start date to make estimates of payout that are up to 93 percent accurate. This degree of accuracy can be attained by frequent and timely updates of the information in the forecasting data base on contracts let and on contracts on the advertisement schedule. Because payments to construction contractors are a major cash flow item for the Virginia Department of Highways and Transportation, as they are in many states, it is anticipated that better forecasts of construction payout will be a valuable aid in the budgetary process.

Setting Priorities of Highway Projects by Successive Subsetting Technique

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ABSTRACT

The development of a technique that can be used to set priorities within a given work category of highway improvement projects is described. After impact categories have been developed, respective priority evaluation measures assess the importance of specific projects within each impact category. The proposed technique of successive subsetting combines the impacts of each candidate project in a work category to determine which projects should be implemented for a given budget. A sample problem consisting of a group of bridge replacement projects is presented to illustrate the application of the technique.

Traditional approaches--weighting factors and developing combined scores of sufficiency ratings--to setting priorities among highway projects have the serious drawback of masking the importance of individual factors. The use of such approaches does not always produce an optimal set of projects, nor can specific reasons be given for selection choices. In the face of increasing highway construction costs and an increasing backlog of improvement projects, greater efficiency in selecting projects for implementation, as well as provision for the defense of the set of projects selected for implementation, must be established.

In this study it is assumed that projects have already been established for given needs. It is also assumed that the best alternative within each project proposal for a particular location has already been chosen. Under these assumptions, a priority-setting technique has been developed that can aid in the choice of the set of projects for implementation within a given work category. This study was sponsored by the Indiana Department of Highways (IDOH) and has been developed for use within its planning division.

HIGHWAY IMPROVEMENT IMPACT CATEGORIES AND PRIORITY EVALUATION MEASURES

When priorities are determined for individual projects within a work category or functional classification, significant types of impacts must be determined. After this, methods for measuring the extent of these impacts must be developed to describe the importance of each project. An impact category is defined as the general impact type that has a specific importance level within a work category. A priority evaluation measure is the value that represents the importance of a project with respect to a given impact type.

SUCCESSIVE SUBSETTING

The major problem in using a priority-setting technique is that available data are mostly subjective and have a low degree of accuracy. Consequently, in the proposed technique, it is assumed that impacts of highway improvements cannot be measured precisely and that, if they can be, the limits of accuracy are quite large. It is assumed that all projects in each impact category can be lumped only approximately into a small number of groups. The members of each group will then have about the same impact value or priority evaluation measure.

The key to this technique is that each smaller group or subset may also be divided into additional smaller groups using different evaluation criteria. A representation of the successive subsetting opera-