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Systems analysis of project cash flow management strategies

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Cash flow management is one of the most important determinants of the success of construction project management. Overdraft, retainage, financing, payment and billing policies constitute the most significant financial issues that contractors must plan, control and manage for the successful completion of construction jobs. Particularly, in an attempt to reduce project costs, contractors must balance cost savings of material discounts due to early payments and extra interest expenses because of additional overdraft. Through identifying feedback loops in project cash flows, a system dynamics model is developed for project cash flow management. The model is flexible to incorporate typical front-end and back-end loading cash flow management strategies and provides an interactive predication of project cash flows. A warehouse project is discussed to demonstrate how various cash flow strategies improve overdraft financing requirements and profitability. Especially, the analysis shows an 11% reduction on overdraft requirements while using an overbilling strategy, and 30% reduction if the trade credit strategy is implemented.

Keywords: Project cash flow, overdraft, cash flow management strategies, system dynamics, scenario analysis.

Introduction

Cash flow management is one of the most critical issues when contractors build projects. Poor cash flow management may result in inadequate working capital and thus undermine the sustainability of a project. Lack of cash to support a firm's day-to-day activities causes more contractor failures than inadequate management of other resources (Kangari, 1988; Pate-Cornell *et al.*, 1990; Kaka and Price, 1991). Effective cash flow management involves forecasting, planning, monitoring and controlling of cash receipts and payments. Project cash flow is generally computed based on estimated cost and revenue over the construction period. In a construction contract, the owner generally requires the contractor to provide a schedule of values that appears as an S-curve of the estimated progress and costs over the life of project construction. This curve is the basis for progress payments from the owner to the contractor. It is obvious in project construction that progress payments lag behind project expenses unless the contractor frontloads the schedule of values. The time lag creates a large gap between progress payments and construction expenses, and thus makes it necessary for the contractor to obtain overdraft financing for the project. The contractor must accurately estimate the cost curve and cash flow schedule to determine the financing requirement. Furthermore, the estimated cash flow is used to monitor and control project progress. And it is considered an important benchmark for owners and contractors to identify early warning indicators of cost overruns and schedule delays.

Construction firms use spreadsheet or other software packages to estimate project cash flows. The computerized estimation is developed with the integrated cost-schedule method, which involves a detailed project schedule with full costing based on the bill of quantities. Cash is considered a resource and allocated to construction activities according to the project estimate and schedule. Halpin and Woodhead (1998) illustrated this method by constructing a simple bar chart of the project, assigning costs to the bars, and smoothly connecting the projected amounts of expenses over time. As discussed in the following section, however, the cost-schedule integration method fails to explicitly

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identify cash disbursements from project expenses. For many cost items, cash collections and disbursements deviate far from expenses and revenues in terms of timing and amount. A recent study conducted by Park *et al.* (2005) illustrated the significant difference between cash outflows and project expenses due to time lags in payment.

Early studies also developed a few statistical models for estimating project cash flow including the polynomial regression models (Bromilow, 1978; Peer, 1982; Isidore and Back, 2002), the phase polynomial model (Boussabaine and Elhag, 1999), the Weibull-Linear model (Tucker, 1986), the logit models (Kenley and Wilson, 1986; Kaka and Price, 1993), the sin model (Miskawi, 1989) and the neural network model (Boussabaine and Kaka, 1998). Kenley (2003) provided a comprehensive review of these alternative cash flow models.

Research work has also been conducted on cash flow forecasting and management across multiple projects or at a company level. Navon (1996) developed a company-level cash flow management system that can forecast cash flow at the organizational level with the advantage of accepting projects with varying degrees of detailing levels. Reinschmidt and Frank (1977) presented a probabilistic cash flow management model to help project managers examine the interactive effects between alternative project schedules and cash flow. Kenley (1999, 2003) discussed how a well-managed construction organization could generate extra cash through operations which could be used for reinvestment. This cash flow management strategy has been observed in the industry and was termed 'cash farming'.

Nevertheless, the dynamics of cash flows in a construction project has not yet been systematically investigated. Accurate predication of project cash flows depends upon both project operation characteristics and contractor's own financial policies. The integrated impact of typical cash flow management strategies, including frontloading, overbilling, trade credit and subcontracting, has not been explored. It has been pointed out that detailed payment conditions and cash flow management policies should be incorporated into the model to accurately predict cash flows (Chen *et al.*, 2005). Interactions among project entities and feedbacks within cash flow management were also ignored in the earlier research. Consequently, the mechanism of how external constraints and construction activities, for instance, rework, line of credit, delay and acceleration, and material discount, holistically affect project cash flow is still unknown. This paper presents a systematic model for project cash flow. The model is developed based on system dynamics and can help contractors plan and manage project cash flow. A warehouse project is used to demonstrate the model's capability for analysing various cash flow management strategies.

Construction costs and cash flows

Cash flows are different from revenues and expenses. There are non-cash revenues and expenses. The timing of cash receipts and payments may not coincide with the recording of revenue and expense account transactions. At a company level, cash receipts and payments are classified into three categories of activities: operating, investing and financing activities. While operating activities are associated with the actual products and services provided by a company, investing and financing activities include activities that relate indirectly to the central, ongoing operation of a business. Investing and financing activities result in cash receipts and payments but may not be contained in revenue and cost accounts. For example, an equipment purchase, normally classified as an investing activity, involves a significant amount of upfront cash payment that would be depreciated over the service life of the equipment. Therefore, cash payment will be much higher than production expense during the purchase period. In the succeeding periods, however, the depreciation cost will inflate considerably and no actual cash payment will be made. Furthermore, cash collections and disbursements may lead or lag behind corresponding revenue and expense items. This timing difference is reflected by the change of accrual accounts, such as receivables, prepaid expenses and inventory accounts. One must adjust each revenue and expense item for the effect of accruals to generate a cash flow statement.

For a construction project where the contractor receives progress payments, three unique characteristics have significant influence on project cash flow. First, project billing charges and cash receipts usually occur only once during each month. As determined in the contract, the contractor may receive cash payments several weeks after billing date. Second, monthly cash payments from the owner are less than billing charges due to retainage. The owner withholds part of monthly payments to encourage the contractor to perform work in a timely manner and to promote compliance with the quality requirement. Third, the contractor can often defer paying subcontractors and sometimes suppliers by operating a pay-when-paid clause. As a result, cash disbursements to subcontractors and suppliers may lag far behind construction expenditures.

Other cost items may also include cash disbursements that deviate from construction expenses. Construction costs consist of labour, material, equipment and overhead expenses that are expended or allocated to construction activities. Cash payment for labour is regularly made one or two weeks after the cost is incurred because labour law requires all labour to be paid on a weekly or bi-weekly basis. Cash payment for materials is generally ahead of or behind the time point when the material expense is recorded. Depending upon billing policies and material characteristics, the time point when the materials become a billable item to the contractor may be different from the time point when the materials become a billable item to the owner. For example, off-the-shelf materials may become a billable item to the contractor when the materials are ordered or delivered. Commonly, the contractor is given a 15- or 30-day grace period to pay for material bill. The same materials can become a billable item to the owner when they are incorporated into the construction project. On the other hand, custom-made materials may require the contractor to make a deposit or prepayment before fabrication begins. The owner occasionally pays for these custom-made materials after they are delivered and safely stored at the construction site, but before they are incorporated into the project.

Equipment costs and overhead expenses may be recorded and billed to the owner at the time point when cash payments have not been made. When the equipment is owned outright and managed at the company level, there may be little cash payment associated with ownership expense. If the equipment is leased or purchased on a loan, the contractor usually makes significant cash outlays on a monthly basis. Furthermore, cash payments for job overheads, e.g. a site office, temporary facilities, premiums on bond and insurance, will have been made before beginning construction work. But the contractor may have to bill the owner and receive reimbursement of such overheads over several payment periods. Additionally, many front-end loading techniques have been identified in project construction that cause actual cash flows to substantially deviate from the expenses and payment schedule (Halpin and Woodhead, 1998). For example, use of mobilization costs, unbalanced pricing, overbilling and other project cash flow management strategies would improve cash balance and generate positive cash flows much earlier. Therefore, accurate prediction of project cash flows must take into account the cash management policies.

Model for project cash flow management

Systems thinking of project cash flow

Effective project cash flow management must be based on accurate forecasting of cash flow schedules and synergistic integration of different cash flow management strategies. Project cash flow characterizes a time-based S-curve, which is in essence driven by project operations. From a systems thinking standpoint, project cash flow is an integrated, dynamic process that consists of reinforcing and balancing loops with delays. At a prime contractor level, cash disbursements for direct labour, raw materials and subcontractor costs result in project cash outflow. Cash collections from the owner constitute project cash inflow. Additionally, project cash disbursements and collections are continuous. Cash received from the owner is used to make payments to workers, vendors and subcontractors for labour and material costs incurred during the construction period. These expenses are marked up with overhead and profit to the owner. The total amount creates a new invoice that will generate cash inflow later. This dynamic process is defined as the payment loop in the project cash flow system (R1) as shown in Figure 1.

There are two retainage loops accompanying the project payment loop. Retainage is a sum withheld from progress payments to guarantee timely completion of a project. Although alternative methods exist, the owner usually retains 10% of the completed work from each payment until the withheld amount reaches 5% of the contract amount. The owner's retainage is later paid to the contractor after the project is finally accepted by the owner. In addition to the owner's retainage, the prime contractor may withhold the same account, 10% in this case, of the work value completed by subcontractors. In most subcontracts, the 'pay-when-paid' clause allows the prime contractor to pay the subcontractor retainage after the prime project is accepted and paid by the owner. The owner's and subcontractor's retainage, along with project operation, constitute two retainage loops: the owner's retainage loop (R2) and the subcontractor's retainage loop (R3).

Cash inflow from project operation normally lags behind project cash outflow. When the cash balance is insufficient to pay workers and suppliers, the contractor must obtain temporary financing. The borrowed money becomes a debt for the project and needs to be paid back periodically with an amount of interest calculated at an agreed upon interest rate. Therefore, two feedback loops are identified as the principal repayment loop (R4) and the interest payment loop (R5). Likewise, if the contractor has a positive cash balance, he should always put the money into a savings account and transfer it to a checking account at the last minute when a payment becomes urgent. This practice enables the contractor to generate as much interest as possible. This forms an interest revenue loop (R6) and the higher the cash balance, the greater the generated interest.

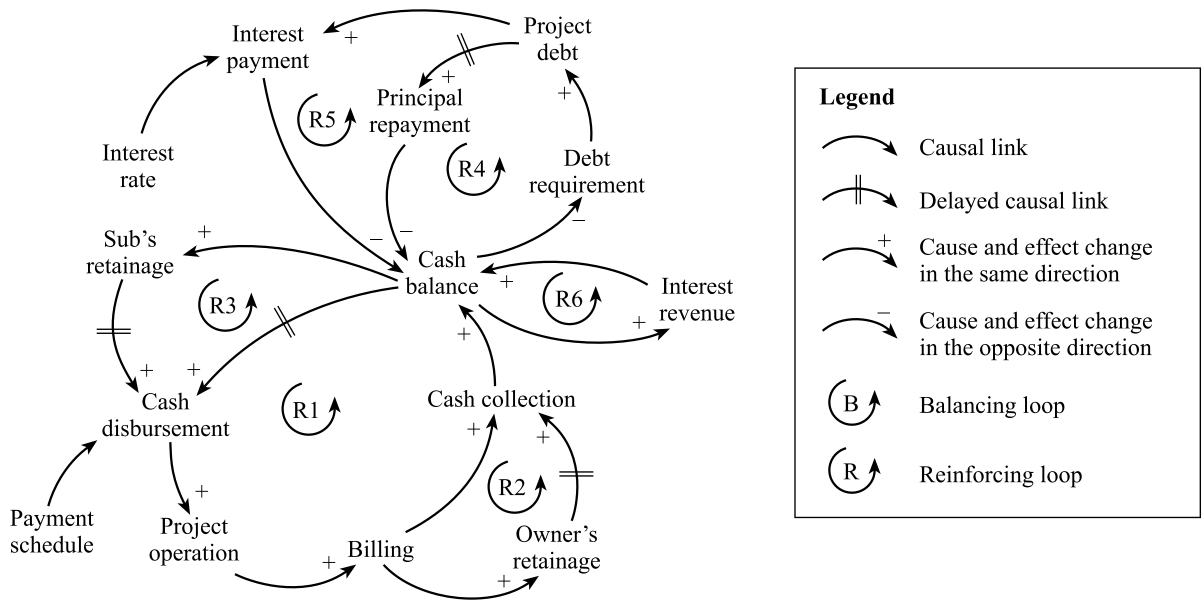

Figure 1 Feedback loops in project cash flow

A system dynamics model

Systems thinking, as a unique approach to describe and model complex systems, has its root in system dynamics that was first introduced by Forrester in the early 1960s. It has been used to examine various social, economic and environmental systems, where a holistic view is important and feedback loops are critical to understand interrelationships. During the past 10 years, research efforts have been made to use system dynamics to analyse construction projects and organizations (Ford and Sterman, 1998; Ogunlana *et al.*, 2003; Park and Pena-Mora, 2003; Ibbs and Liu, 2005).

The system dynamics approach focuses on system behaviour over time. The dynamic behaviour is determined by the system elements and structure that is described as stock variables, flow variables and feedback loops. Stock variables are accumulations. They characterize the state of the system and provide it with memory and inertia. Flow variables are rates that alter stock variables over time so that they alter the state of the system. Auxiliary variables are other types of variables that consist of functions of stock variables. Auxiliary variables differ from stock variables and change values immediately (Sterman, 2000). All variables are linked by arrows that represent influence among variables. There are two types of feedback loops: balancing feedback loops (labelled B) and reinforcing feedback loops (labelled R). Balancing loops, which are also titled negative loops, operate whenever there is goal seeking behaviour. The process works to close the gap between a goal and an actual condition. Reinforcing feedback loops which are also called positive loops are the engines of organizational growth and decline. They are commonly referred to as having snowball effects. The feedbacks, together with time delays, will determine the dynamic behaviour of a system. Readers are referred to Senge (1990) and Sterman (2000) for a detailed explanation of system dynamics. With the feedback loops identified in a construction project system, project cash flow can be modelled and analysed to determine the impact of project operations and cash flow management policies.

This paper uses Vensim DSS version 5.5 to model and simulate project cash flow management. Stock variables are represented by rectangles. Flow variables are represented by a pipe pointing into/out of the stock. The cloud icon represents an input or output that is outside the boundary of the system. Auxiliary variables are linked directly by arrows (Figure 2). The project cash flow management model includes several modules that are described as follows. Each module consists of a few system equations that define the system structure and therefore determine system behaviours. Those equations are presented in the Appendix.

Cash balance module

The cash balance module is the frame of the model and includes cash flow from operating and financing activities for the period of the project construction. It connects the other modules and is shown with the outline of the model (Figure 2). When the contractor submits an invoice to the owner, the amount becomes a debit balance in accounts receivable. The owner reviews the bill and pays the invoice several weeks later. This cash collection generates a cash inflow to the

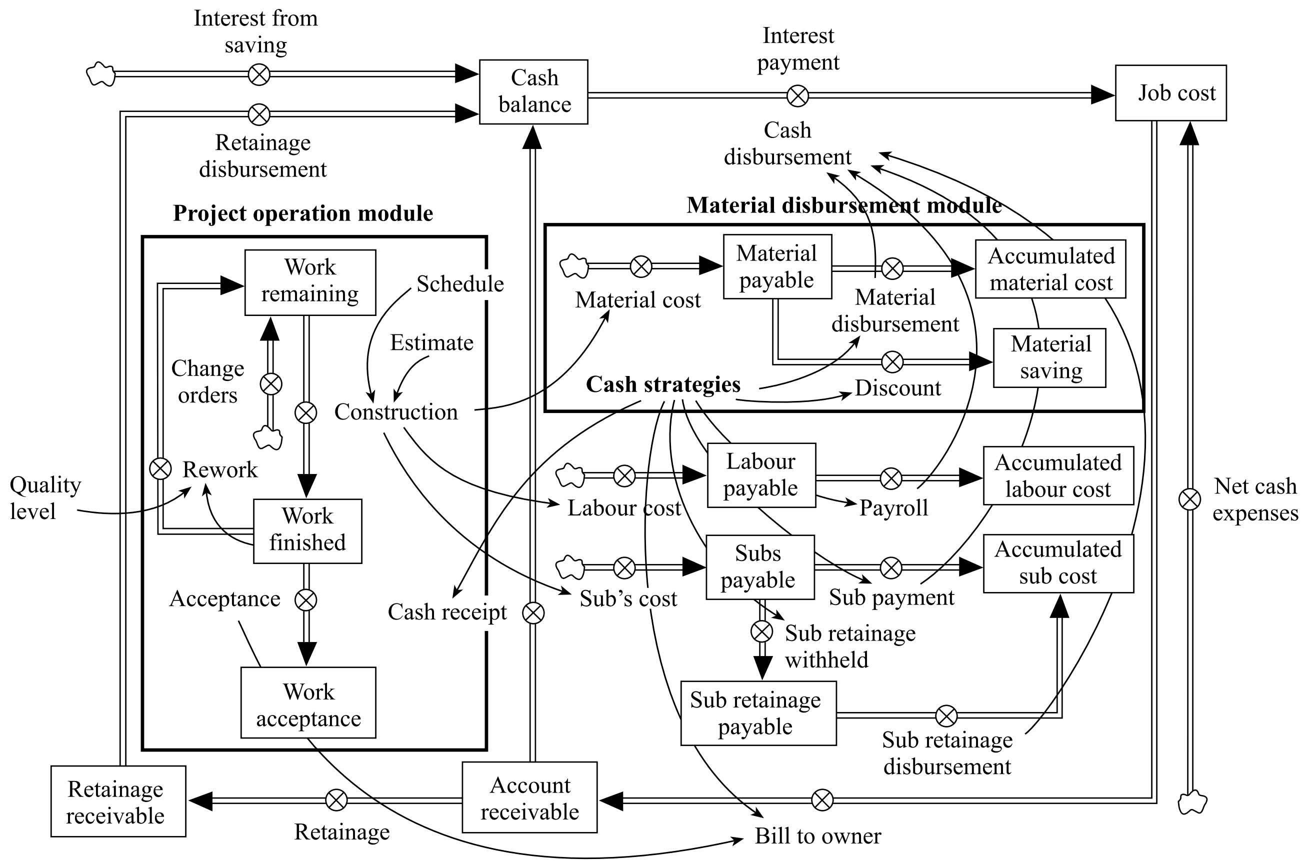

Figure 2 System dynamics model for project cash flow management

contractor, and the cash balance account increases correspondingly. Meanwhile, a percentage of each payment will be withheld as a retainage until 50% of the work has been completed. Thereafter, no further retainage will be held; however, the accumulated amount shall be stored in the retainage receivable account until project completion and acceptance. Interest from saving accounts is another source of cash. The contractor might put the money in a saving account or a checking account with interest. On the other hand, cash payments from operating activities constitute project cash outflow. The major cash disbursement activities in a construction project include material disbursements, payroll, payments to subcontractors, and sometimes payment for equipment. These activities are described with the following equations.

$$CB_t = \sum_{k=0}^{t} (CR_k + RR_k + IS_k - CD_k) \quad (1)$$

$$CR_t = BTO_{t-d} - RR_{t-d} \quad (2)$$

where CB_t is the cash balance at time t, CR_k is the cash receipt at time k, RR_k is the retainage reimbursement at time k, IS_k is the interest revenue from saving accounts, and CD_k is the cash disbursement that will be calculated in other modules, BTO_{t-d} is the bill to owner at time t-d, and d is the time delay.

Material disbursement module

The material disbursement module describes cash activities with respect to material invoices, payments, discounts and material cost overrun. It is shown in Figure 2. Within this module, the material cost schedule and material payment schedule are modelled separately. The difference between the material cost and payment is reflected by the material payable accrual account. The material invoice is determined by the material cost, which is ultimately determined by the construction operation. Commonly, the contractor orders materials in advance and requires the supplier to follow a material delivery schedule. The supplier bills the contractor when the materials are received and accepted by the contractor. To guarantee the required materials are available when they are needed, the contractor may store materials on site for several days or weeks. This practice requires an early material delivery before it is urgently needed. As more and more contractors apply the lean concepts and the just-in-time material management system, the inventory holding period has been extremely shortened. Different material management systems will be modelled in the project cash flow model by frontloading the material cost schedule. Frontloading the material cost schedule for a week indicates that the material delivery schedule is a week ahead of actual material cost schedules. Therefore, the contractor would store on site construction materials sufficient to last a week.

The material invoice is required to be paid after a grace period specified in the material purchase contract. Most suppliers offer an early-pay discount for shelf materials to encourage contractors to pay the bill promptly. A typical construction material discount term (called credit term) in the construction industry is '2/15, n/30', meaning that a discount of 2% is allowed if the invoice is paid within 15 days. Otherwise, the full amount is due within 30 days. It is the contractor's decision to take the discount or not. If he decides to take advantage of the discount, he is moving the material payment schedule forward. This frontloading practice would adversely affect the project's financial position by increasing the overdraft balance. Additional debt has to be financed to cover the increased overdraft balance. This would generate additional interest expense and limit future project financing if the limit of credit is reached. The material disbursement module incorporates this typical practice and assesses material payment policies by changing the material payment schedule.

Project operation module

Cash flow is determined by project operation. The project dynamic model was first modelled by Kim (1988) and Cooper (1993) who identified rework and undiscovered errors respectively. Rework happens in almost any construction project, though the amount varies. As Cooper (1993) estimated, the delay in the discovery of errors is approximately $^1/_4$ to $^3/_4$ of the time required to design the original work. The errors must be fixed, which results in a rework loop. This research uses a slightly modified version of the project model suggested by Cooper (1993) and Kim (1988). This paper considers the impact of change orders and integrates costs and time functions (Figure 2). At the core of the project operation module is the project flow from the work remaining to the work finished, along with a rework loop. Similar to the quality assurance work flow model developed by Lee *et al.* (2007), the finished work is inspected and accepted before it is billed to the owner. In addition to the rework, the scope of work may be changed through change orders due to uncertain site conditions, changed owner requirements, etc. Costs incurred by rework and scope change are modelled as separate flow variables in other modules. For example, increased material cost due to rework is included as cost overrun in the material disbursement module.

Other modules

The project cash flow model also includes other cash activities with respect to labour payments, equipment charges, and subcontractor invoicing and disbursements. The labour payment module and subcontractor payment module are similar to the material disbursement module. In the labour payment module, labour cost is computed according to the labour cost estimation and payroll schedule. The labour is normally paid one or two weeks after the labour costs are incurred. If the project is delayed or rework occurs, the labour costs escalate and the increase in cash disbursements depend upon the duration of the additional work. The subcontractor payment module follows a similar mode, except for a retainage branch. The prime contractor withholds a percentage of work completed by the subcontractor. The amount of the subcontractor's retainage becomes a stock, named subcontractor retainage payable. The retainage is finally paid after the project is complete and accepted. A detailed list of the equations for this module is available upon request.

Systems analysis of cash flow management strategies

The system dynamics model allows flexible cash flow management strategies. The key areas of project cash flow management include cash collection and disbursement, cash planning and budgeting, and optimal cash balance. This process involves the development and implementation of project cash flow management strategies with an objective to maximize project cash flow. The model presented in the previous section can help prime contractors determine the project overdraft and optimize cash flow by analysing the impact of different cash flow management strategies. Three types of project cash flow management strategies can be analysed in the model, namely, front-end loading, back-end loading, and optimal cash balance strategies.

Front-end loading strategies

Front-end loading strategies denote all techniques that concentrate cash receipts from project operation in an early period. Typical front-end loading techniques in project construction include mobilization costs, unbalanced pricing and overbilling. First, mobilization costs are those costs incurred in moving personnel and equipment, establishing site facilities prior to beginning construction. In heavy construction projects, mobilization costs may exceed 10% of the contract amounts and many owners will guarantee advance payments. Proper billing of mobilization costs will give an immediate boost in cash flow and improve project cash balance. Second, unbalanced pricing refers to overpricing work items done early in the project and underpricing work items to be completed in the later stage. It could be just a disproportionate allocation of project cost, called a mathematically unbalanced bid, and/or a materially unbalanced bid which usually results in an extra added cost to the owner due to changes in the bill of quantities. Although a materially unbalanced bid is generally rejected, a mathematically unbalanced bid is not prohibited especially when the lack of balance does not pose an unacceptable risk to the owner (Nadel, 1991; Wang, 2004). Third, contractors are able to improve cash flow by billing materials that have not been installed. This type of front-end loading technique is commonly allowed by many owners. According to the Engineers Joint Contract Documents Committee's (EJCDC) C-700 Article 14.02 and the American Institute of Architects' (AIA) standard contract documents A201 9.3.2, the value of materials stored at the site is allowed to be added to the application for payment if the materials are suitably stored and not likely to be lost on account of theft or deterioration. If the owner agrees in advance, the value of materials and equipment stored off site or in a supplier's shop may also be included in the contractor's invoice for payment (AIA, 1997; EJCDC, 2002). Overbilling is always accompanied by underbilling. When the contractor overbills the owner at an early stage of construction, he must underbill later to offset the extra charge in the overbilling invoices.

Back-end loading strategies

Two widely used back-end loading strategies are trade credit and subcontracting in a construction project. Trade credit exists when a contractor receives materials from a supplier but pays them later. In this sense, suppliers play an important role in project construction as a source of working capital for construction firms (Agapiou *et al.*, 1999). Consider a scenario where the contractor orders and receives materials at the beginning of the month, but the supplier only bills the contractor at the end of the month with a 30-day grace period. The contractor can actually delay cash disbursement for materials for up to eight weeks and therefore use trade credit to support short-term financing. Along with the benefit, trade credit will also increase potential risk exposure. Contractors must carefully plan and manage their trade credit to reduce potential risks of losing the trust of their suppliers (Nicholas *et al.*, 2000). To incorporate a trade credit strategy in the system dynamics model, the researchers specially design the model to include flexible material disbursement schedules, therefore making it possible to simulate the impact of alternative trade credit policies.

Subcontracting is another type of trade credit. Through subcontracting arrangements, the prime contractor uses subcontractors' labour, materials and equipment to build projects, but pays them later. Under a 'pay-when-paid' clause, the prime contractor may defer the project cash disbursements until he receives payments from the owner. Furthermore, withholding retainage for subcontractors' work allows the prime contractor to defer cash transfer until project completion. These subcontracting policies are incorporated into the system dynamics model. The model is flexible enough to conduct what-if analysis to predict the impact of different subcontracting arrangements.

Optimal cash balance

Cash is primarily needed to support daily transactions. In addition to this transaction motive, a contractor must hold additional cash for unexpected requirements, or for precautionary purposes. In a construction project, there are many reasons for cost overruns and emergency needs for cash. However, the opportunity cost of holding excessive cash could be high, especially under high interest rates. The contractor must determine a target cash balance that involves a trade-off analysis of covering cash deficiency and avoiding excessive cash balance. It should be noted that the execution of these cash management strategies depends on the contract format and project negotiation, and therefore may not be possible under certain circumstances.

Case study

Example warehouse project

An example construction project is used to demonstrate the use of the system dynamics model for project cash flow management. The case project is a storage warehouse with around 150 000 square feet under cover. The warehouse is designed to provide storage for grocery and non-food items. The project is scheduled for eight months, and includes 10 contract bid items (major construction activities). The project budget is about $5 million as shown in Table 1. Assume that the direct costs are evenly distributed across the duration of each activity; the weekly direct cost can be calculated based on the cost-schedule integration method. The reader is referred to Cui (2005) for a detailed project description and weekly cost calculation.

Table 1 Project cost estimate

	Item	Labour	Material	Subcontract*	Mark-up	Total
1	Site earthwork	44 000	153 200	Scenario A	23 600	220 800
2	Structural concrete	231 800	349 000	Scenario B	69 600	650 400
3	Special floors	219 800	271 500		59 000	550 300
4	Structural steel	113 000	686 000	Scenario C	95 800	894 800
5	Precast walls	79 200	418 200		59 600	557 000
6	Plumbing & HVAC	127 600	313 600		53 000	494 200
7	Fire protection	96 600	201 000		35 600	333 200
8	Electrical	104 000	250 000		42 000	396 000
9	Roofing	94 400	123 600	Scenario D	26 000	244 000
10	Building finish	255 000	311 300		68 000	634 300
	Total	1 365 400	3 077 400		532 200	4 975 000

Note: * No subcontractor is involved on the base run.

The estimated cost schedule generates an S-curve if it is accumulated over time. The system dynamics model supports both activity-based cost schedule and time-based cost schedule function. This research uses the cost schedule function approach to describe project expenses over time. A regression analysis is conducted to estimate the mathematical function of the cost schedule. As earlier research has pointed out, three-, four-, or five-order polynomial functions best fit the project cost schedule (Navon, 1996). Two three-order polynomial equations for the labour cost curve and material cost curve are estimated with the standard linear regression method. The estimated equations with high R^2 indicate the percentage of the dependent variables that can be explained by the independent variable. With t indicating time in weeks, the equations are estimated as:

$$\textit{Material Cost Schedule: } MC = -0.0153t^3 + 0.164t^2 + 10.433t \; (R^2 = 0.9083) \quad (3)$$

$$\textit{Labour Cost Schedule: } LC = -0.0082t^3 + 0.1854t^2 + 2.8325t \; (R^2 = 0.7461) \quad (4)$$

One of the disadvantages of polynomial functions is possible negative cost values as time increases. One way to solve this problem is to set a range of time to avoid negative values. This paper, however, impose the non-negative constraint on the cost schedule functions so that the model is capable of simulating various payment schedules by moving cost schedule curves. One could avoid the negative cost problem if activity-based cost schedules are used.

As compared to material cost and labour cost, mark-up is relatively stable for each activity. It is estimated to be 12% of direct cost over the project duration. The model uses a constant mark-up ratio to indicate the overhead and profit charged for each activity.

The cash disbursement schedules are determined based on typical construction practices and cash flow management policies. In the base run, no subcontractor is involved in the construction. The project payment from the owner is received four weeks after invoicing. Labour is paid every two weeks. Material costs are paid four weeks after billed. A 2% discount will be applied if the material bill is paid in two weeks. It is further assumed that the interest rate for project financing is 12% per year or 0.3% per week. Vensim DSS 5.5 was used to simulate the project cash flow without implementing any front-end or back-end loading strategy.

Curve 1 in Figure 3 describes the cash balance under base run. Under the base run, the project progresses as scheduled. It is obvious that the contractor needs temporary financing in this project because of the negative cash balance during the whole period of project construction. The cash balance becomes overdraft at the end of the first eight weeks. The overdraft trend accelerates after week 8 and continues to its peak at week 24. The overdraft remains over $800 000 during weeks 20 to 28. After that, the overdraft trend reverses. The cash balance condition gets better and better. At week 36, the cash balance finally gets back to black. The cash balance curve (overdraft) reflects the characteristics of project construction. Construction expenses are higher in the middle of the construction period, as compared to earlier and later stages of construction. There are more than 10 weeks when the overdraft exceeds $500 000—all of which fall in the middle of the construction period. The maximal overdraft is $994 000 and occurs in the 24th week. The cyclic behaviour with a period of four weeks represents a monthly (in this case, four weeks) payment schedule from the owner. If the construction

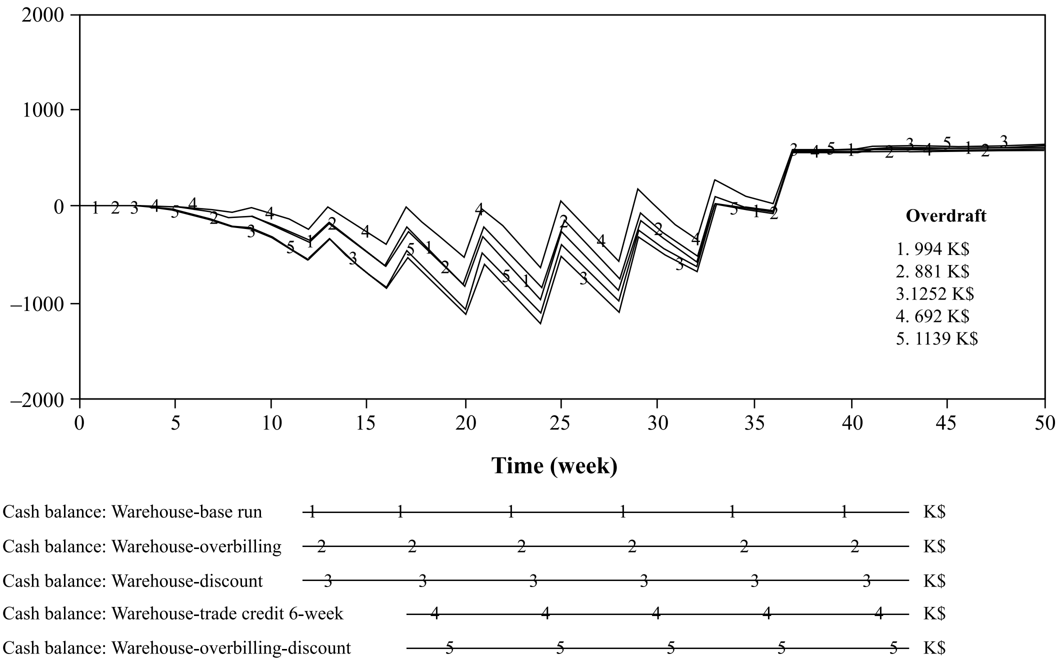

Figure 3 Cash balance under different scenarios

contract requires a two-week payment period, one can change the variable of owner payment delay from four to two weeks. And the project cash flows would demonstrate a cyclic behaviour with a period of two weeks.

Scenario analysis was also conducted to evaluate the impact of different cash policies and construction operation on the project financing requirement. Several cash flow management strategies discussed above will be analysed to illustrate the merits of the model and how the analysis could improve project cash balance. A summary of the overdraft impact of various cash management strategies is shown in Table 2. Readers should note that the integrated cash management strategy combines several strategies including overbilling, material discount and subcontracting.

Cash policy analysis

Overbilling and underbilling

The maximum overdraft constitutes the basis of project financing. To reduce interest payments and increase project profitability, contractors always try to reduce the amount of overdraft financing. Three typical front-end loading strategies are available to move forward the project revenue curve and thus reduce the cash overdraft. However, unbalanced bids and inflating mobilization costs are unfavourable in this project because they could place the owner in a very risky situation. The contractor's unit prices had been compared to engineering estimates to prevent such unbalanced bids and inflating mobilization costs. Overbilling, therefore, was considered as an alternative strategy to improve

Table 2 Overdraft impact of cash management strategies

Cash management strategy	Overdraft			
	Start week	End week	Peak week	Max value ($)
Base run	1	37	24	–994 000
Overbilling	1	37	24	–881 000
Trade credit	1	33	24	–692 000
Subcontracting A	1	37	24	–972 000
Subcontracting B	1	37	24	–829 819
Subcontracting C	1	37	24	–620 000
Subcontracting D	1	37	24	–982 000
Integrated strategy	1	33	28	–869 000

project cash flow. Overbilling is different from unbalanced bidding in that the contractor overbills the material costs for those materials that are stored at the site or off site and have not been used in the project. As compared to unbalanced bidding, the overbilling strategy is less risky. After all, under an overbilling scenario, the owner pays the contractor for the materials and owns the materials before they are used and installed.

Through overbilling, the contractor improves his/her financial condition by frontloading the schedule of values so that the contractor has a receivable on the books or, better yet, the cash in the bank. To show the dramatic impact of overbilling, the example project is simulated with an average of 10% overbilling for materials during the first half of the project period. The overbilling strategy allows a contractor to bill the owner for the materials stored on site but not installed in the project. During the second half of the project period, the contractor switches to an underbilling policy to balance the project cost. Eventually, the total project price is unchanged. The result is demonstrated in Figure 3 where curve 2 represents cash balance under the 10% overbilling strategy. This strategy benefits the contractor in that more cash will be received earlier and less debt is needed. Eventually, the cash balance condition is improved by reducing the maximum overdraft. As shown in Figure 3, the maximum overdraft under the overbilling scenario is \$881 000, as compared to the base run value of \$994 000, which means an 11.4% improvement in cash balance. The under/overbilling strategy not only benefits the contractors by improving cash balance, but also improves the project performance. The simulation indicates that at the end of construction, the cumulative project profit would increase by \$3500 due to a reduction in interest payments.

Impact of trade credit

The contractor may also back-end load the cash payment schedule to reduce the need for overdraft. Trade financing is one back-end loading strategy that can be analysed in the system dynamics model. Especially, the model integrates the evaluation of trade credit and material discount effects. Consider a 2% discount offered by the material supplier for early payment, or a typical credit term ‘2/15, n/30’. If the contractor decides to take the discount, the material invoices must be paid within two weeks rather than the usual four weeks. If the materials are delivered at the beginning of the month but billed at the end of the month, the contractor may delay the material payment for six to eight weeks after the material cost is incurred. In other words, the contractor either moves forward the material payment schedule for two weeks to take advantage of material discount, or moves backward the schedule to delay cash outflow. Figure 4 shows the material payment curve under various scenarios. It is obvious that frontloading or backloading the material payment curve will have significant impact on the project overdraft (see curve 3 and 4 in Figure 3). On the other hand, taking a material discount generates substantial savings in construction cost and eventually increases project profit. As compared to a six-week trade financing scenario (curve 4 in Figure 3), an additional \$53 000 cash (profit) will be generated from the

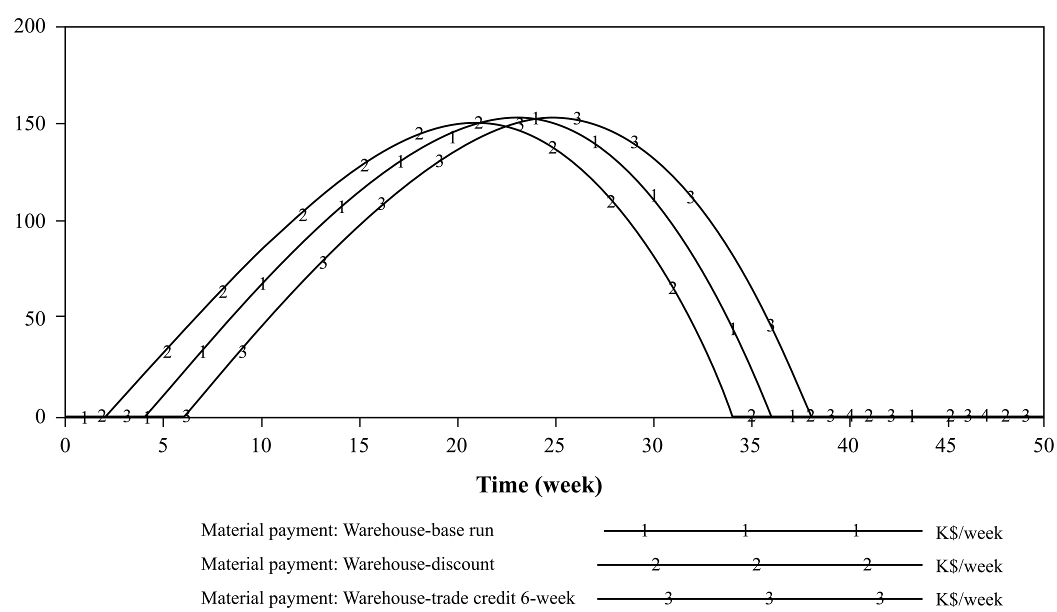

Figure 4 Impact of trade credit

material discount by the end of the construction (curve 3 in Figure 3).

The analysis also examines the integrated impact of material discounts and the overbilling strategy. While taking a material discount increases project profitability and the overbilling strategy reduces overdraft financing requirements, the integration of material discounts and overbilling would be a better cash flow management strategy. The simulation suggests the optimal cash strategy depends upon the contractor's financing capacity. For example, if the contractor has a quite low credit limit (less than $1 000 000 in this case), they may not be able to successfully complete the warehouse project because of the lack of cash after taking material discounts. Using trade financing would be a better strategy, with a trade-off of reduced profit.

Subcontracting

The contractor can further reduce the overdraft balance and financing requirements by subcontracting specialized work. In addition to self-performing all construction work, four subcontracting scenarios are also identified and evaluated with the system dynamics model in terms of the impact on the project overdraft, including hiring earthwork, concrete, steel and roofing special contractors (Table 1). The scenarios are intentionally selected in pairs (scenario A vs D, B vs. C) with the objective of assessing the impact of subcontract amount and timing on project cash flow. The simulation indicates that all subcontracting activities improve project cash flow. The degree of impact depends upon both subcontract amount and timing of subcontracting. The more the subcontract amount, the less the overdraft financing requirement. The earlier the subcontracting work, the better the cash balance is improved (Figure 5).

It is generally believed that subcontracting will improve project cash conditions, especially where a pay-when-paid clause is included in the subcontract. However, subcontractors may propose a high bidding price when competition is limited and alternative cost control and cash management strategies are not available. The system dynamics model provides an analysis method for evaluating different subcontracting options and cash management strategies. What, when, and how much project items/work should the prime contractor outsource in order to improve project cash flows? When limited negotiation power is available for the prime contractor, which subcontractor should the prime contractor pay more attention to? What is the cost of the pay-when-paid clause if it is not included in the subcontract?

Construction operation analysis

Construction is a risky business. It is necessary in many projects to evaluate the impact of uncertainty on project overdraft financing. The system dynamics model incorporates uncertain construction factors such as rework, schedule risk, cost overrun, etc. In the example project,

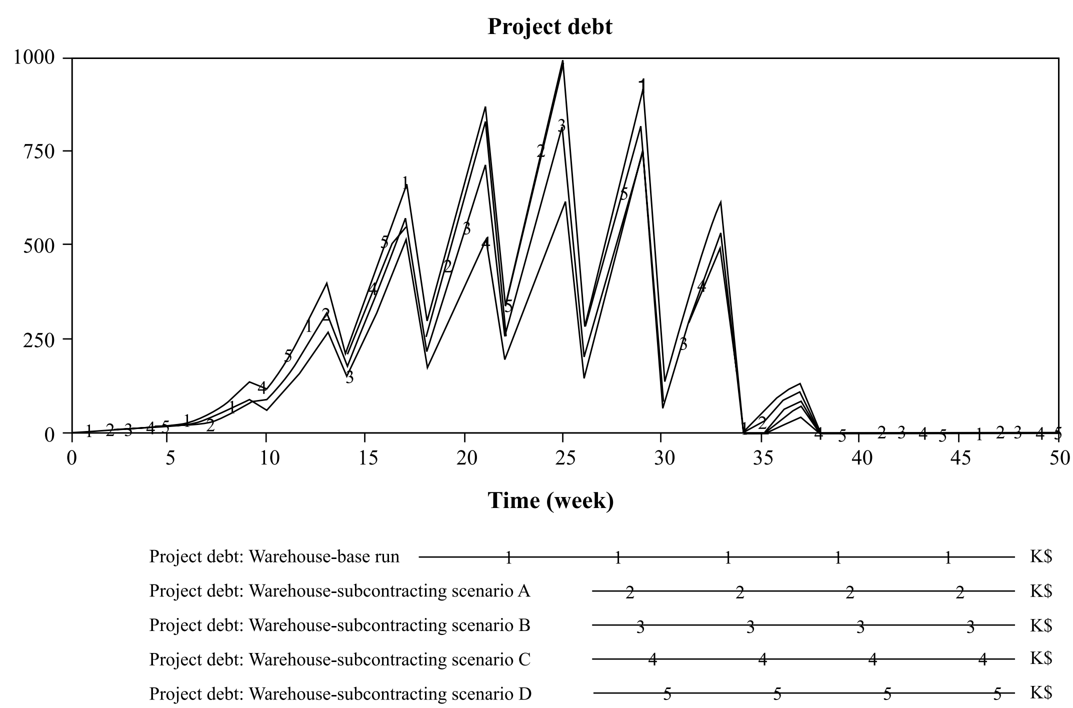

Figure 5 Subcontracting impact

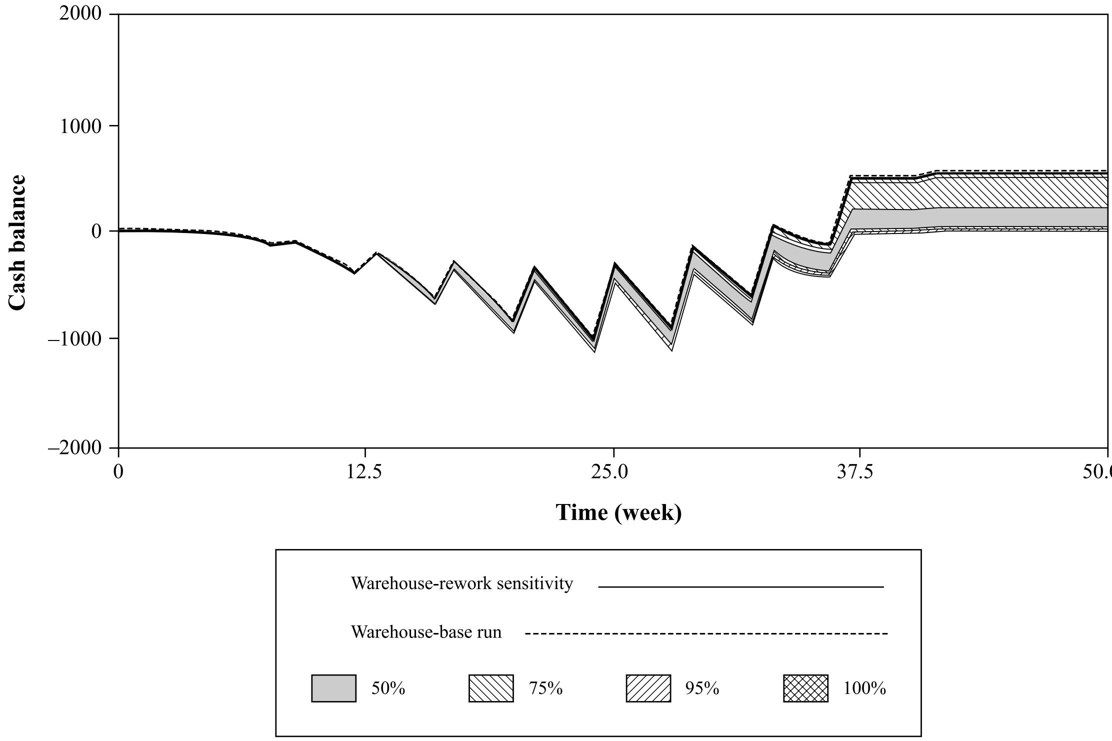

Figure 6 Impact of rework

a sensitivity analysis is conducted to evaluate the effect of uncertain construction performance. Errors and unacceptable low quality lead to rework and extra construction costs. Assuming an up to 5% rework ratio over the whole construction period, the model simulates the project operation and gives the extent of project overdraft under various confidence levels (Figure 6). Similar analysis can be conducted to evaluate the impact of uncertain schedule delay and cost overrun. Readers are referred to Cui (2005) for example analysis of cost overrun on project cash flows.

Conclusion

Using feedback loops to describe project cash flows, the system dynamics model is capable of evaluating the impact of cash policies and project operation on project cash flow. Various front-end and back-end loading cash management strategies are integrated into the model so that simulation and what-if analysis can be used to determine an effective cash flow management strategy. The project cash study demonstrated the capabilities of the system dynamics model for better planning and managing project cash flows.

One of the most important features of this model is the integration of cash flow management strategies into the cash flow prediction. In most construction projects, the selection of cash flow management strategies is to some extent determined by contract types and clauses, which usually need cumbersome negotiation between the prime contractor and other project stakeholders. By changing key parameters in the model, the prime contractor will be able to simulate cash flow conditions under different negotiation scenarios, and therefore evaluate the cost and benefit of specific contract clauses in terms of their impact on project cash flows. The case study demonstrates the impact of various payment clauses in the material supply contract on temporary financing requirements. By using an overbilling and underbilling strategy, the project team could reduce the project overdraft balance by 11.4%. If the trade credit strategy is effectively implemented, another 19% reduction in overdraft requirements would be achieved. Similar research can be conducted to evaluate the cost and benefit of various financial clauses in the subcontract, e.g. with or without a pay-when-paid clause, or a four-week payment period as regards subcontractors. Furthermore, with slight modifications, owners and subcontractors can establish their own cash flow management models and apply them to evaluate the effectiveness of their own cash flow management strategies.

Although the merit of the model is apparent, it should be noted that the current model must be solved via a system dynamics software package. The limitation requires a customization of system parameters for a specific project. Following the framework demonstrated in Figure 2, a project team may also need to modify the model equations in order to evaluate the impact of various cash flow management strategies. Therefore, an unbounded software package is definitely worth further research so that project teams could quickly adjust the model and analyse the financial impacts of different cash strategies.

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Appendix

Model equations

Cash balance module

Account Receivable = INTEG (Bill to Owner – Cash Receipt – Retainage, 0)
Bill to Owner = Job Cost*(1+Markup Ratio) + Overbilling to Owner
Cash Balance = INTEG (Cash Receipt + Retainage Reimbursement-Cash Disbursement + Interest Income, 0)
Cash Receipt = DELAY FIXED (Bill to Owner – Retainage, Project Receivable Delay, 0)
Cash Disbursement = Interest Payment + Payroll + Material Disbursement + Sub Payment
Interest Income = max(0, Cash Balance*Saving Interest Rate)
Interest Payment = Project Debt*Interest Rate
Overbilling to Owner = IF THEN ELSE (Month Counter = 0, Cumulative Overbilling/Weekly Adjusted, 0)
Retainage = IF THEN ELSE (Retainage Receivable<Project Scope*0.05, Min((Project Scope*0.05-Retainage Receivable), Bill to Owner*Retainage Rate, 0)
Retainage Receivable = INTEG (Retainage-Retainage Reimbursement, 0)
Retainage Reimbursement = IF THEN ELSE (Retainage Request = 1, Retainage Receivable, 0)
Retainage Request = IF THEN ELSE (Percentage of Work Done >= 1, 1, 0)
Cumulative Overbilling = INTEG (Overbilling Increase-Overbilling to Owner, 0)
Overbilling = Material Cost* IF THEN ELSE (Time<18, 1, –1)*IF THEN ELSE (Time<=32, 1, 0)
Overbilling to Owner = IF THEN ELSE (Month Counter = 0, Cumulative Overbilling, 0)

Project operation module

Work Accepted = INTEG (Acceptance, 0)
Work Finished = INTEG (+Construction-Acceptance-Rework, 0)
Work Remaining = INTEG (+Rework-Construction, Project Scope)
Rework = (1-Quality Level)*Work Finished
Acceptance = IF THEN ELSE (Month Counter = 0, Work Finished, 0)
Construction = IF THEN ELSE (Percentage of Work Done<1, Project Schedule, 0)
Project Scope = 4442 + Change orders

Labour cost module

Accumulated Labour Cost = INTEG (Payroll, 0)
Labour Cost = Labour Cost Schedule
Labour Cost Schedule = max(0, (–0.0082)*(Time)∧3+0.1854*(Time)∧2+2.8325*Time)*"$ Adjusted"-Subs Cost*Labour Cost Ratio
Labour Payable = INTEG (Labour Cost-Payroll-Labour Cost Overrun, 0)
Payroll = DELAY FIXED (Labour Cost + Labour Cost Overrun, Labour Payment Schedule, 0)

Material disbursement module

Accumulated Material Cost = INTEG (Material Disbursement, 0)
Discount = max (0, Material Payable*Discount Rate)
Material Cost = Material Cost Schedule
Material Cost Schedule = max (0, (–0.0153)*(Time)∧3+0.164*(Time)∧2+10.433*(Time) –Subs Material Cost
Material Disbursement = DELAY FIXED (Material Cost*(1-Discount Rate* Discount0decision) + Material Cost Overrun, Material Payment Schedule, 4)
Material Payable = INTEG (+Material Cost-Discount-Material Disbursement-Material Cost Overrun, 0)
Material Saving = INTEG (Discount, 0)

Subcontracting module

Accumulated Sub Cost = INTEG (Sub Payment + Sub Retainage Disbursement, 0)
Retainage Reimbursement = IF THEN ELSE (Time = 36, Retainage Receivable*Retainage Request/Time to Reimburse Retainage)

Sub Accrual Cost = INTEG (+Subs Cost-Sub Billing, 0)
Sub Billing = IF THEN ELSE (Month Counter = 0, Sub Accrual Cost/Time to Accept, 0)
Sub Payment = DELAY FIXED (Sub Billing-Sub Retainage Withheld, Project Receivable Delay, 0)
Sub Retainage Disbursement = IF THEN ELSE (Retainage Reimbursement>0, Sub Retainage Payable/Time to Reimburse Retainage, 0)
Sub Retainage Payable = INTEG (+Sub Retainage Withheld-Sub Retainage Disbursement, 0)
Subs Cost = IF THEN ELSE (Time >= 21:AND:Time <= 28, Sub Estimate/Item Schedule, 0)
Subs Payable = INTEG (+Sub Billing-Sub Payment-Sub Retainage Withheld, 0)