CASH FLOW OPTIMIZATION AND VISUALIZATION OF RESIDENCE HOUSING FOR BUILDERS

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ABSTRACT: *Cash flow management is widely considered to be a key issue within the construction industry, especially for residential homebuilders. Cash flow in the residential housing industry involves multiple stakeholders, such as lot developers, banks, clients, trades, and builders; usually the builder initiates a complex plan involving lot procurement, construction investment, and housing sales, which has the potential to lead to more profitable solutions for the builder. This research develops a decision support system subject to variable developer and bank payment schedules, and is based on a twofold objective: (1) Maximize cumulative (negative) cash flows, subject to the guaranteed net present value (NPV) for developers and bank. The optimum solutions help builders to stay within the bank overdraft limit and reduce the pressure of cash demands for builders. (2) Maximize builder's NPV and increase the NPVs of developers and banks as much as possible. With the multi-objective optimization, the win-win optimal solutions serve as negotiation strategies between these stakeholders. The proposed decision making system is highlighted by the application of visualization techniques; two types of visualization techniques, i.e., a combined Excel and add-in and a preliminary Augmented Reality (AR), are utilized to illustrate the optimizing process and the optimal solutions, with the cash inflows, outflows, and the net cash flows for different time periods displayed dynamically. A case study based on a project in Edmonton, Canada is utilized to demonstrate the proposed methodology.*

KEYWORDS: *Cash Flow Management, Cash Flow Optimization, Residential Housing, Builder, Visualization, Decision Support System.*

1. INTRODUCTION

Cash flow management is a vital issue in the construction industry domain, with large amounts of cash flow occurring daily. This issue is imperative, especially for residential homebuilders, since the cash flows of builders involve multiple stakeholders, such as lot developers, banks, clients, and trades. Homebuilders manage cash flows to meet the requirements from different stakeholders, and make profits as well. Usually homebuilders initiate a complex plan involving lot procurement, construction investment, and housing sales; however, initial planning has the potential to lead to more profitable solutions for homebuilders.

The existing literature has addressed various aspects of cash flow management. Peer and Rosental (1982) showed that cash flow management is an indispensable tool for construction companies, where poor cash flow management could lead to company failure due to lack of working capital, even if projects are profitable. The significance of cash flow management has garnered attention from construction managers and researchers, and many studies with respect to cash flow management have been conducted in recent decades. Elazouni and Gab-Allah (2004) examined the effect of balancing the financial requirement with the cash available during the same period using an integer-programming finance-based scheduling method to satisfy the finance availability constraints. Navon (1996) developed an adequate cash-flow management system. With an examination based on the expense flow, income flow, and time lag, Navon raised the idea of creating a mathematical model of cash-flow management for the organizational level, and followed with a computer program written on this basis. More recently, a project-level cash flow forecasting model from the contractor's viewpoint has been introduced (Park et al., 2005). Park et al. mainly focused on a forecasting cash flow model for construction projects, with consideration of both variable cost and time lag, by developing two types of models: a cash-in model and a cash-out model. Lucko (2010) reviewed the literature on financial and project management, and examined how to accurately determine financing fees, particularly interest. This study presented the derivations of financing fees and the logarithmic expressions, which were compared with the approximations from the literatures. In a subsequent study, Lucko (2011) addressed the cash flow optimization from the view of contractors, and proposed an innovative modeling method with singularity functions. Based on a case example, this study modeled cash

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flow with singularity functions and optimized profits utilizing simulated annealing. In 2008, an investigation based on cash flow for optimization profit in multi-project environments was conducted (Liu et al., 2010). Chen et al. (2010) introduced an ant colony optimization approach for optimizing discounted cash flows. They introduced the notion of using net present value (NPV) to determine the difference between discounted cash inflows and outflows. They also developed several functions in conjunction with various algorithms to maximize the final NPV.

Visualization is another important research area within the construction domain, and generally visualization research can be categorized into virtual reality (VR) and augmented reality (AR). Through the use of visualization technology, construction processes can be visualized before breaking ground and monitored throughout construction. Errors can be detected and monitored through visualization such that the project manager can address them proactively, which reduces construction cost and duration. Due to the advantages of visualization, a considerable amount of research related to construction visualization has been conducted in recent decades, especially with the development of powerful computers. Other researchers have focused on construction operation visualization technology. Al-Hussein (1999) developed a 3D animation for planning crane operations, and used the 3D animation to facilitate crane selection, location, and onsite utilization. Kamat and Martinez (2001) developed a methodology which combined operation simulation and visualization, and described a first version of a general-purpose 3D visualization system that is simulation and CAD software-independent. The visualization contributes to the construction monitoring system when used during construction. For example, a new framework in which productivity and carbon footprint are measured and visualized was proposed by Heydarian and Golparvar-Fard (2011). In 2012, the same research group (Memarzadeh and Golparvar-Fard, 2012) presented a new carbon footprint monitoring tool that enables contractors and managers to reliably and effectively benchmark, monitor, and visualize the expected and released embodied carbon footprint of a construction project. The proposed method is based on a state-of-the-art technology generating multi-dimensional augmented reality models, and the expected and released embodied carbon footprint of a project are both represented in the model.

Although numerous research studies examining either cash flow management or visualization in construction have been conducted, to the authors' knowledge no research has combined the two, and visualization technology has not been utilized in cash flow management. This paper describes the use of visualization in cash flow management in order to supply a more efficient tool for decision making. This paper is organized as follows: first, a quasi-model using Microsoft Excel is presented which is developed to interpret the continuous net cash flow at a time unit of day, based on the forecasting data from a homebuilder in Edmonton, Canada; the further development of the optimization model to minimize the negative cash flow and maximize the homebuilder's NPV is then described. The use of two techniques to visualize the optimization process and optimized cash flow, and a comparison of the two techniques, are then presented.

2. RESEARCH OBJECTIVE AND METHODOLOGY

The aim of this research is to manage and optimize cash flows from the perspective of residential homebuilders, assisting homebuilders to meet the requirements from different stakeholders and to make more profitable plans; meanwhile, this research explores the application of visualization technology for cash flow management and optimization. The research objective is described in greater detail in the following section.

2.1 Research objective

This research is based on the assumption that all capital investments and funds to cover cash deficits are withdrawn from the bank loan, and that the builders have no liquidity. Cash flow optimization and management after the cash flow profiles are streamed constitute the primary objects of this research, and the research objective is twofold:

Objective 1: maximize the minimum cumulative cash flow (negative cash flow) for homebuilders. Cash flow comprises cash inflows and cash outflows, where the construction direct cost, indirect cost, lot payment, and interest are calculated in order to determine the cash outflow, and the bank payment is computed as the only cash inflow. The minimum cumulative cash flow is maximized, subject to bank and developer payment schedules. The maximized minimum cash flow helps builders to stay within the bank credit limit.

Objective 2: maximize the NPV for builders. Subject to the different payment schedules of bank and developers, and the guaranteed NPVs for bank and developers, the builder's NPV is optimized; according to the optimal solution, win-win financial strategies are provided for financial negotiations.

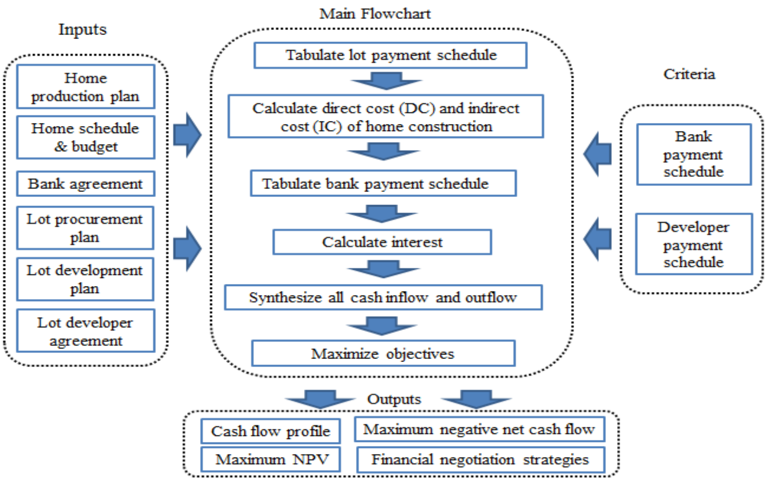
Besides the above research objective, the application of visualization technology for cash flow management and optimization is another aim and of this research.

2.2 Research methodology

A homebuilder's development plan consists of the input information of the research methodology, including house production plan, house construction schedule and budget, lot procurement plan, lot payment schedule, lot developer agreement, and bank agreement. Based on the input information, the cash outflow is calculated, accommodating lot payment, house construction direct cost (DC), indirect cost (IC), and interest. The cash inflow is determined by payments from the bank. By synthesizing the cash inflow and outflow, the cash flow

Fig. 1: Research methodology

profile and the cumulative cash flow profile are streamed accordingly. Subject to variable bank payment



schedule and lot developer payment schedule, two types of optimization are modeled corresponding to two optimization objectives: (1) cash flow profile optimization: the minimum cumulative cash flow is maximized, subject to variable bank and developer payment schedules and guaranteed developer and bank NPVs; this optimization model results in the maximum negative cumulative cash flow, which assists builders to meet the bank overdraft limit; (2) optimization of builder NPV: in this model, multi-objective optimization is applied, where the aim is to maximize the builder's NPV; the NPVs of developers and banks are also increased as much as possible. The optimization process is subject to different bank and developer payment schedules, and the win-win outputs serve as the financial negotiation strategies. The output of the research methodology is twofold corresponding to two research objectives: (1) cash flow profile and maximized minimum cash flow, which relieve homebuilders of cash flow pressure and help homebuilders to stay within bank overdraft limit; (2) maximized NPV for homebuilders, and win-win financial negotiation strategies, which benefit homebuilders, the bank, and developers. The research methodology is summarized in Figure 1, and the optimizations are modeled as Equations (1) to (13).

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2.2.1 Cumulative cash flow profile and optimization

$$Max.\left(Min(CC_t)\right) \tag{1}$$

$s.t.$

$$CI_t = BP_t \tag{2}$$

$$CO_t = LP_t + DC_t + IC_t + I_t \tag{3}$$

$$NC_t = CI_t - CO_t \tag{4}$$

$$I_t = NC_{t-1} \times i \tag{5}$$

$$CC_t = CC_{t-1} + NC_t \tag{6}$$

$$NVP_B = \sum_{t=0}^{N} \frac{BP_t}{(1+i)^t} = NPV_{B0} \tag{7}$$

$$NVP_{Dj} = \sum_{t=0}^{N} \frac{LP_{jt}}{(1+i)^t} = NPV_{D0} \tag{8}$$

Where CI_t is the cash inflow at time t, CO_t is the cash outflow at time t, NC_t is the net cash flow at time t, CC_t is the cumulative net cash flow at time t, BP_t is the bank payment at time t, LP_t is the lot payment at time t, DC_t is the direct construction cost at time t, IC_t is the indirect construction cost at time t, I_t is the interest at time t, i is the interest rate, NVP_B is the net present value for the bank, and NVP_{Dj} is the net present value for developer j.

2.2.2 NPV optimization for homebuilders

$$Max.(NVP) = Max.\left(\sum_{t=0}^{N} \frac{NC_t(LP_t, BP_t)}{(1+i)^t}\right) \tag{9}$$

$$s.t.$$

$$CI_t = BP_t \tag{10}$$

$$CO_t = LP_t + DC_t + IC_t + I_t \tag{11}$$

$$NC_t = CI_t - CO_t \tag{12}$$

$$NVP_B = \sum_{t=0}^{N} \frac{BP_t}{(1+i)^t} \geq NPV_{B0} \tag{13}$$

$$NVP_{Dj} = \sum_{t=0}^{N} \frac{LP_{jt}}{(1+i)^t} \geq NPV_{D0} \tag{14}$$

Where: NPV is the net present value of the builder, CI_t is the cash inflow at time t, CO_t is the cash outflow at time t, NC_t is the net cash flow at time t, BP_t is the bank payment at time t, LP_t is the lot payment at time t, DC_t is the direct construction cost at time t, IC_t is the indirect construction cost at time t, I_t is the interest at time t, i is the discount rate, NVP_B is the net present value for the bank, and NVP_{Dj} is the net present value for developer j.

2.2.3 Cash flow visualization

As in other areas of construction research, the application of visualization technology promotes the presenting of research and the results. By utilizing visualization techniques, the cash flow management and optimization process can be highlighted and demonstrated dynamically. In our research, two types of visualization technique are utilized and compared. (1) Combined Excel and add-in: by applying integrated simulation and optimization software, i.e., OptQuest in Crystal Ball, the optimization process can be visualized with the values of cells changed dynamically. Furthermore, in this paper, the integrated simulation and optimization are combined with the graph-generating technique in Excel, and the cash flow profiles are visualized dynamically during the optimization process. (2) Preliminary Augmented Reality (AR) technique: A preliminary AR is utilized to demonstrate the optimal cash flow scenario on a predefined image. The application of AR highlights the presenting of the optimal cash flows with a dynamic tool and predefined building information (image).

3. CASE EXAMPLE

A builder in Edmonton, Canada provided the following cash flow information: (1) House production plan data for the time period between August of 2013 and June of 2015: the detailed information includes house job number; predicted contract date between the builder and the home owner; construction start date, allowing for a lag of 60 days for pre-construction stage; and estimated home price and cost (excluding lot cost). (2) House cost-schedule integrated data: this includes all houses listed in the production plan, with cost and schedule broken down to the purchase order level (construction tasks). (3) Bank agreement data: this lists the bank payment schedule as agreed upon with the builder; the bank payment schedule is presented using bank payment milestones with specific descriptions as in Table 1. In this research, it is assumed that the builder deals with one bank only and there are six milestones for bank payments, each with a corresponding payment percentage. (4) Developer agreement data: this data assigns the payment schedule to the developers as stated in the contract between the developer and the builders. The developer payment schedules are presented using developer payment schedules as in Table 2; in this research, there are three lot developers who deal with the builder, and there are eleven milestones for each developer payment, each with a corresponding payment percentage. (5) Lot procurement plan: this plan lists the predicted lots to be purchased and their respective prices, expected developers, and purchasing dates. An annual interest rate of 4% is adopted in this research. The building phases, including development phase, construction phase, and possession phase; developer payment milestone; and bank payment milestone are illustrated in Figure 2.

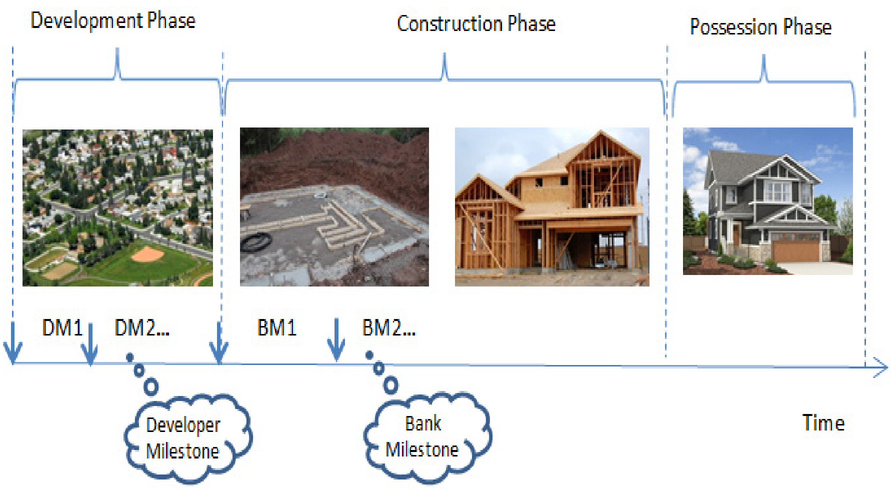

Fig. 2: Building Phase and Milestone.

Table 1: Original Bank Payment Schedule.

Payment Milestone	Description	Percentage of Home Price
1	Sign contract	5%
2	Start Construction	0%
3	Stake out	27%
4	Painting	25%
5	Possession date	33%
6	Lean hold back release	10%

Table 2: Original Developer Payment Schedule.

Developer 1	Payment Milestone	1D1	1D2	1D3	1D4	1D5	1D6	1D7	1D8	1D9	1D10	1D11
	Payment Percentage	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	0%
Developer 2	Payment Milestone	2D1	2D2	2D3	2D4	2D5	2D6	2D7	2D8	2D9	2D10	2D11
	Payment Percentage	5%	0%	25%	0%	25%	0%	0%	45%	0%	0%	0%
Developer 3	Payment Milestone	3D1	3D2	3D3	3D4	3D5	3D6	3D7	3D8	3D9	3D10	3D11
	Payment Percentage	20%	0%	0%	20%	0%	20%	0%	20%	0%	0%	20%

3.1 Cash flow profile

With the input data retrieved and sorted, the cash inflows and outflows are calculated in daily units. After synthesizing the cash inflows and outflows, the original net cash flow profile and cumulative cash flow profile are generated, as shown in Figure 3. The original minimum cumulative cash flow is determined to be -$5,998,747.

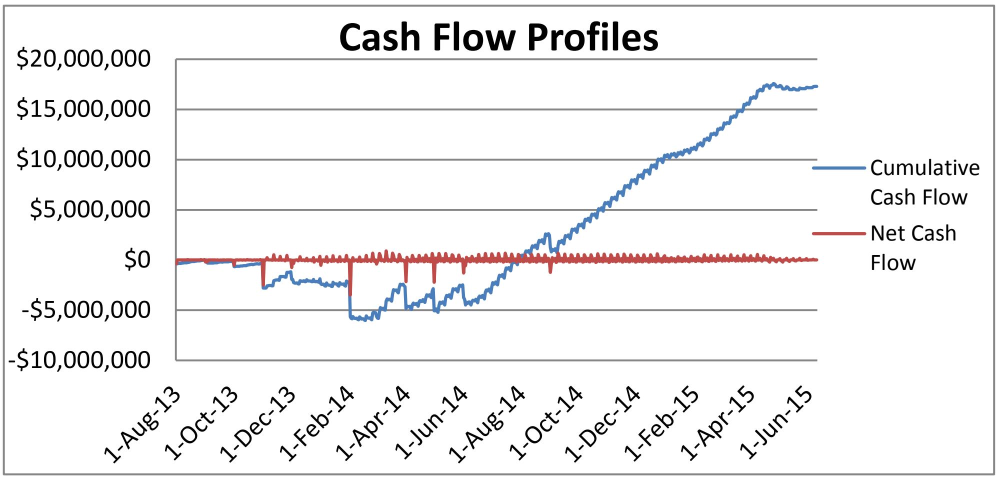

Fig. 3: Cash Flow Profile.

3.2 Minimum cumulative cash flow optimization

In order to assist the builder to stay within the bank overdraft limit, the minimum cumulative cash flow (negative cash flow), which is subject to the variable payment schedules and the guaranteed NPVs of developers and bank, is maximized. The cash flow profile optimization model (Equation (1) to (8)) is applied for this case; the maximized negative cumulative cash flow is $200,142, and the optimal solutions are as presented in Tables 3 and 4 and Figure 4. In this case, Microsoft Excel Solver is utilized as the optimization tool, since OptQuest cannot find a feasible solution for the fixed constraint requirements of this model.

Table 3: Optimal Bank Payment Schedule for Maximized Negative Cumulative Cash Flow.

Payment Milestone	Description	Percentage of Home Price
1	Sign contract	53%
2	Start Construction	0%
3	Stake out	0%
4	Painting	0%
5	Possession date	0%
6	Lean hold back release	47%

Table 4: Optimal Developer Payment Schedule for Maximized Negative Cumulative Cash Flow.

Developer 1	Payment Milestone	1D1	1D2	1D3	1D4	1D5	1D6	1D7	1D8	1D9	1D10	1D11
	Payment Percentage	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Developer 2	Payment Milestone	2D1	2D2	2D3	2D4	2D5	2D6	2D7	2D8	2D9	2D10	2D11
	Payment Percentage	18%	0%	0%	0%	0%	0%	0%	0%	0%	0%	82%
Developer 3	Payment Milestone	3D1	3D2	3D3	3D4	3D5	3D6	3D7	3D8	3D9	3D10	3D11
	Payment Percentage	42%	0%	0%	0%	0%	0%	0%	0%	40%	0%	18%

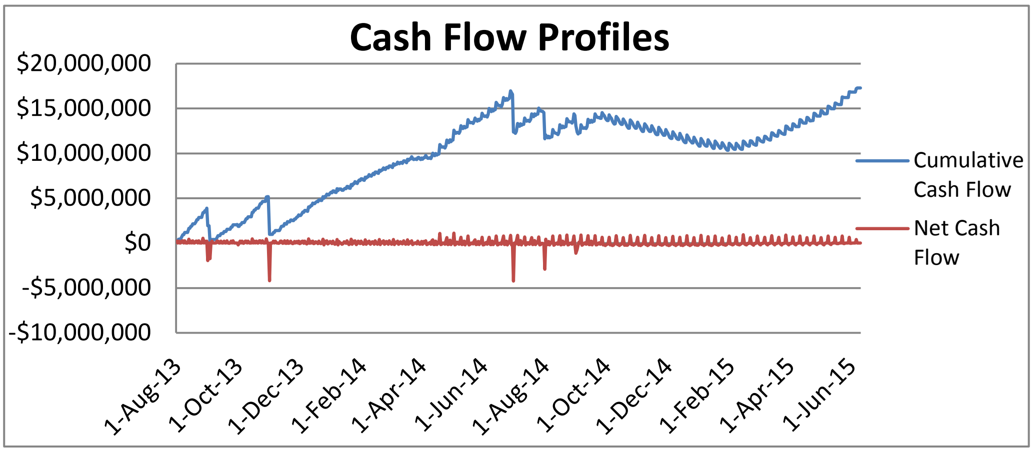

Fig. 4: Optimized Cash Flow Profile I.

3.3 NPV optimization

The building plan initiated by the builder is not the optimal solution, and has the potential to make more profits for the builder, the bank, and the developers through multi-objective optimization. In order to improve the profitable solutions, the NPV optimization model (see Equations (9) to (13)) is applied, with the builders' NPV maximized. The NPVs of the developers and the bank are also increased as much as possible. The optimizing tool, OptQuest, is utilized for this case, generating optimization solutions which provide win-win strategies for the stakeholders; at the same time, the optimization process is visualized. The builder's NPV increases from the original value of

$14,446,134 to the maximum value of $15,838,977. The optimal solutions are summarized in Tables 5 and 6 and Figure 5.

Table 5: Optimal Bank Payment Schedule for Maximized Builder's NPV.

Payment Milestone	Description	Percentage of Home Price
1	Sign contract	100%
2	Start Construction	0%
3	Stake out	0%
4	Painting	0%
5	Possession date	0%
6	Lean hold back release	0%

Table 6: Optimal Developer Payment Schedule for Maximized Builder's NPV.

Developer 1	Payment Milestone	1D1	1D2	1D3	1D4	1D5	1D6	1D7	1D8	1D9	1D10	1D11
	Payment Percentage	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
Developer 2	Payment Milestone	2D1	2D2	2D3	2D4	2D5	2D6	2D7	2D8	2D9	2D10	2D11
	Payment Percentage	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
Developer 3	Payment Milestone	3D1	3D2	3D3	3D4	3D5	3D6	3D7	3D8	3D9	3D10	3D11
	Payment Percentage	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

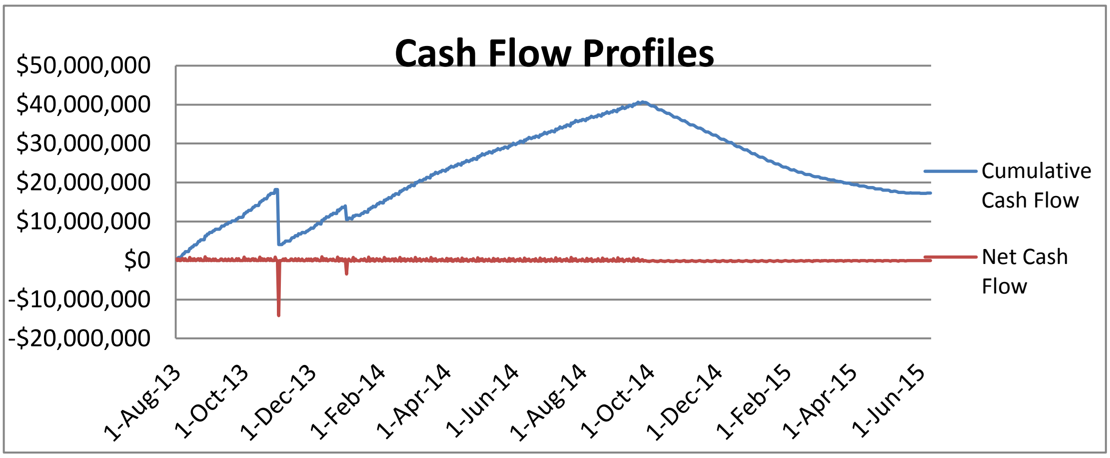

Fig. 5: Optimized Cash Flow Profile II.

3.4 Cash flow and optimization visualization

Two visualization techniques are applied in this research:

1) Optimization process visualization:

This research applies an integrated simulation and optimization software, i.e., OptQuest in Crystal Ball, which promotes the cash flow optimization visualization; the values in cells are changed dynamically along with the simulation and optimization process. Furthermore, in this research, the cash flow profiles are connected with the changeable cells, resulting in a dynamic cash flow profiles. The combination of the application of software and the dynamic cash flow profile generating technique provides an impressive and dynamic visualization of cash flow optimization. The combined interface of OptQuest and Excel is shown in Figure 6; the performance chart of OptQuest is demonstrated in Figure 7, in which the vertical axis presents the value of the objective function and the horizontal axis displays the simulation generation.

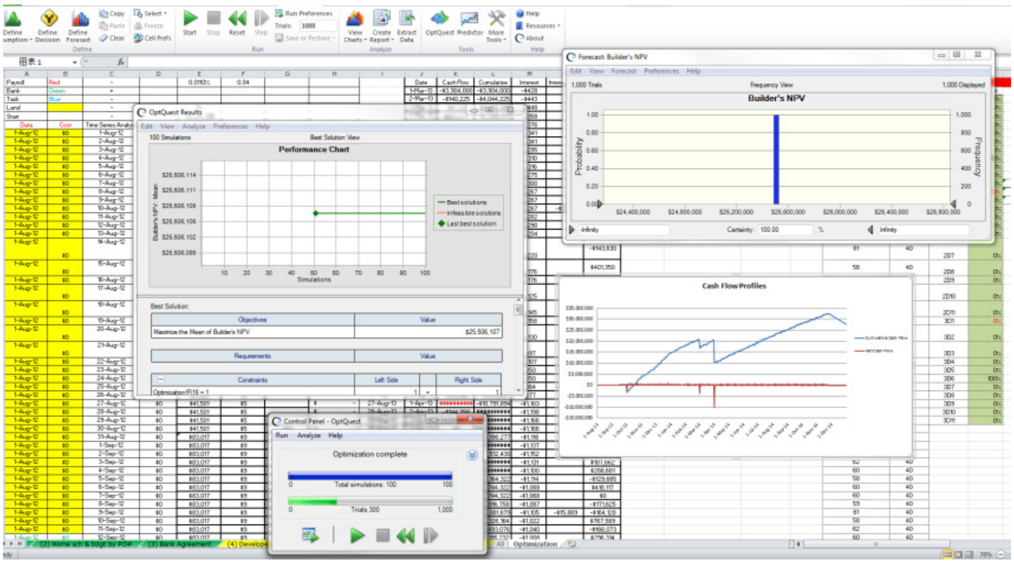

Fig. 6: Combined interface (OptQuest and Excel).

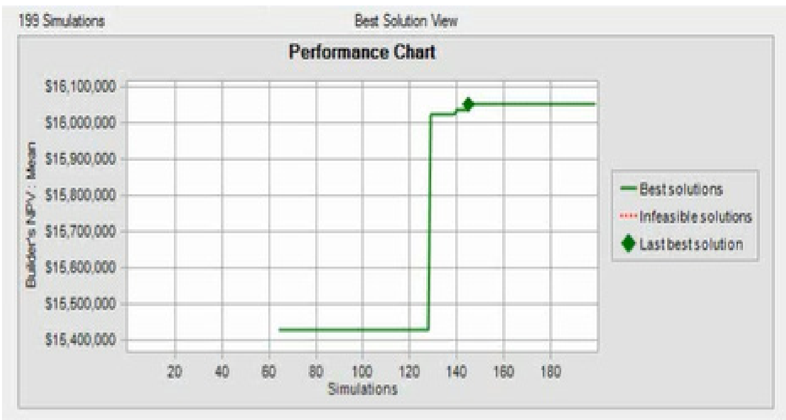

Fig. 7: Performance chart of OptQuest.

2) Best-case scenario demonstration:

A preliminary AR is utilized in this research to demonstrate the optimal cash flow solutions, connected with a predefined image. A snapshot of the optimal solutions is shown in Figure 8, in which the optimal cash inflows and outflows are demonstrated on the cash flow chart, with the cash barrel displaying the net cash flows. The background is a predefined image of a house. A snapshot of a pure animation of the optimal solution is displayed in Figure 9.

Fig. 8: A snapshot of AR.

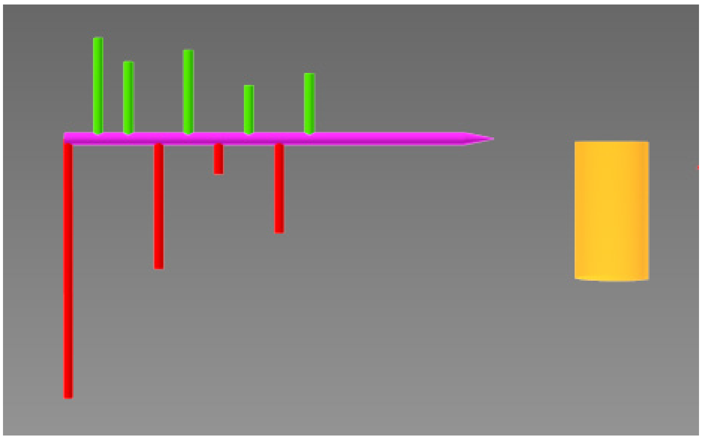

Fig. 9: A snapshot of animation.

4. CONCLUSION

This research addresses two important issues related to cash flow management for residential builders: (1) Minimum cumulative cash flow optimization: subject to variable payment schedules and guaranteed NPVs for developers and bank, the builder's minimum cumulative cash flow has been optimized. The minimum cumulative cash flow is related to the amount of overdraft from the bank, and the optimization helps the builder to satisfy the bank's overdraft limit. (2) NPV optimization: as an important index related to net benefit, the builder's NPV has been optimized subject to variable developer and bank payment schedules; the NPVs of developers and the bank have also been increased as much as possible, i.e., multi-object optimization has been applied to address this issue. Using a case study in Edmonton, Canada, this research has demonstrated that, through the optimizations, the minimum cumulative cash flow improved significantly from -$5,820,855 to $200,142. Also, the NPV of the builder increased from $14,446,134 to $15,838,977, and the NPVs of all of the developers and the bank increased. The optimal solutions alleviate the pressure of cash demands for the builder, and the optimized solutions provide win-win strategies for financial negotiations. During the optimization, two different visualization techniques have been applied to dynamically illustrate the optimizing process and the optimal solutions. With the application of OptQuest the optimization process has been visualized, focusing on the potential solutions and the optimization process. Meanwhile, by utilizing a preliminary AR, the best-case scenario has been demonstrated dynamically. The application of visualization technology has been shown to promote cash flow management and optimization.

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