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Research Article

Novel mathematical model for investing decisions for self-financing building construction project portfolios

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Abstract:

Financially, project portfolios can be completely self-reliant when their required liquidity is merely obtained through reinvesting the profit of the finished projects and the initial capital of the owners. However, the firm can only perform some profitable projects despite maximizing wealth owing to a shortage of funds. In such cases, projects' implementation can be phased as a practical solution to satisfy financial deficiencies. Therefore, decision-makers are involved in finding the optimum selection and scheduling of the self-financing phase-able project portfolios. This research proposes a mathematical model for the problem of building construction project portfolio with simultaneous consideration of the reinvestment strategy and phasing strategy at the enterprise level. In this case, an integer programming model to maximize the investment's net present value is presented. The proposed model provides a decition support system for property developers to select and schedule self-financing phase-able building construction project portfolios, in this context, the model's applicability is illustrated in a case example.

Keywords: *Building project portfolio management, Integer programming, Phasing strategy, self-financing financial structure.*

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Introduction

Under the guidance of strategic goals, organizations have to manage a set of projects simultaneously. Indeed, it can be said that most companies (approximately 84% of them) involve managing concurrent multi-projects (Lova, Maroto, and Tormos, 2000). As a result, a multi-project environment is the nature of most businesses, especially the real estate industry (Liberatore, Pollack-Johnson, and Smith, 2001). In line with this, real estate developers purchase a large tract of raw land to sell developed land or parcels to consumers. Therefore, they schedule a portfolio of ready-to-start building construction projects. Depending on the size and complexity, each building project imposes time and consumes resources. In terms of financial resources, building construction projects bring about a long investment period with no positive cash flow. Moreover, involving a concurrent multi-project environment makes the financing issue more acute. Therefore, poor management of financial resources leads to inoperable idle assets such as uncompleted buildings. In This case, owners undergo a waste of opportunity for other investments (Zhong et al., 2019). Researchers propose a reinvestment strategy and a phasing strategy to overcome the financing limitations of building project portfolios (Li *et al.*, 2016; Shafahi & Haghani, 2018a; Zhong *et al.*, 2019).
Reinvestment strategy means the reuse of generated profit from finished projects to finance the portfolio again; therefore, owing to the improvement of the cash position, the reinvestment strategy will provide new solutions for stakeholders. In particular, the financial structure of the project portfolio can be deemed self-financing, meaning there is no inflow of money except initial capital. Thus, the organization is operated with internal revenues and the investors' initial capital. It should be noted that relying on internal financial reserves has gained popularity since it is the simplest and cheapest financing procedure. On the other hand, property developers can benefit from a phasing strategy to avoid fixed idle assets. Based on developers' policies, projects can be divided into operable parts. Therefore, selecting and managing portions within the portfolio is the primary concern. In this case, financial restrictions may conclude a potential project to be accepted or rejected partly or entirely; moreover, interruptions can occur in the continuous process of projects portions implementation (Shafahi & Haghani, 2018a; Shafahi & Haghani, 2018b; Zhong et al., 2019).

Regarding selecting the projects within the portfolio, this issue originates from Markowitz (1952), a problem like the well-known backpack problem. This issue was later developed, and more nature of the natural world, such as resource constraints, probabilistic conditions, dynamic environment, the relationship between the projects, and so on., were subsequently considered in this issue (Markowitz, 1952, 1959; Dikmen, Birgonul, and Ozorhon, 2007; Zuluaga, Sefair and Medaglia, 2007; Petit, 2012; Deng *et al.*, 2013; Janssen, Manca and Volpe, 2013; Lim & Wimonkittiwat, 2014; Beşikci, Bilge, and Ulusoy, 2015; Asta *et al.*, 2016; Toffolo *et al.*, 2016; Wauters *et al.*, 2016; Geiger, 2017).
One of the most commonly used issues combined with the selection of project portfolios is the selection and scheduling of projects, which means that projects are first selected for execution in the portfolio, and then the commencement time of the selected projects or their activities is determined (Kolisch & Padman, 2001; Chen & Askin, 2009).
To improve financial constraints, Belenky (2012), for the first time, adopted the reinvestment strategy to cover the financial need of the project portfolio. In the presented case, a solution has been proposed to maximize the number of projects selected within the range of the portfolio as well as maximize the amount of money obtained at the end of the portfolio.
Wang et al. (2016) modeled the problem of selecting and timing the project portfolio by considering the reinvestment strategy, technological dependence between projects, and the time value of capital. The goal is to maximize the portfolio's income.
Jafarzadeh et al. (2015) proposed a flexible investing time for self-financing project portfolio selection and scheduling problems. In this regard, a significant amount of time is considered in calculations; therefore, selection and scheduling are performed without any time limitation. In this case, the optimum investing time is achieved.
Since projects are divisible, it is possible to minimize investment amount, produce liquidity in a shorter time and eliminate the opportunity cost of the idle fixed asset. Zhong et al. (2019) presented a divisible project portfolio selection and scheduling, where the objective function maximizes financial resources minus fixed assets costs regarding the time value of money. In this research, the required investment amount for each project is supposed to have a linear relationship with the project completion percentage. Although the proposed model eliminates the opportunity cost of idle assets through project divisibility, it is not adaptable for some projects, especially construction projects. For instance, the construction of a single-story house should reach a minimum completion percentage to generate profit and for vertical development of the upper floors.
Shafahi and Haghani (2018) concentrate on building construction project portfolio selection and scheduling. In the presented model, phasing capability, prerequisites relationship of the predefined phases, and reinvestment strategy have been considered. The objective function is to maximize the net present value of the entire portfolio. Mirkhorsandi et al. (2022) presented a two-objective mathematical model in order to maximize the net present value of investment and minimize idle renewable resources during the project portfolio. In this model, the selection and scheduling of projects within a project-oriented organization is considered due to the limitation of renewable and non-renewable resources, the existence of a prerequisite relationship between project activities, considering the time value of capital for financial resources, and finally using the strategy of generating income while working. Also, the modeling of expectations of

managers and investors in a self-financing phasable and non-phasable project-oriented organization from the point of view of cash management and optimization is presented in (2023).
Finally, uncertainties are considered with in the project portfolio selection problem. (Li et al., 2019; Zarjou & khalilzadeh, 2021; Ranjbar, Nasiri and Torabi, 2022)
The model presented in this paper contributes to the literature on the building construction project portfolio selection and scheduling problem by performing a more accurate cash flow calculation. In this context, the optimal self-financing phased land developing procedure will be offered to the developers. Simply put, Table 1 summarizes the literature on the self-financing project portfolio selection and scheduling issue.

Table 1. summary of the literature on the self-financing project portfolio problem

Category	Belenky 2012	Wang et al. 2016	Jafarzadeh et al. 2015	Shafahi & Haghani 2018	Tofighian et al. 2018	Zhong et al. 2019 Li et al. 2019	Ranjbar et al. 2022	This article
Reinvestment strategy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Projects cash flow modeling and consideration	No	No	Yes	No	No	No	No	Yes
Phasing strategy	No	No	No	Yes	No	Yes	Yes	Yes
Considering building construction project portfolios	No	No	No	No	No	No	No	Yes
Flexible scheduling for construction projects	No	No	No	No	No	No	No	Yes

The rest of this paper continues as follows. First, the mathematical modeling of the self-financing Phase-able building project portfolio selection and scheduling problem is fully described. Then the applicability of the model is illustrated in a case example. Finally, the paper finishes with a conclusion.

Problem definition

Suppose a real estate developer purchased a large tract of land and defined building projects within (set V). Subsequently, the creation of real estate should be organized as self-reliant, in which financing of the portfolio is only confined to the generated income of the finished projects plus the initial investment (P). In this context, developers encounter the selection and scheduling of a portfolio of several building construction projects and determine the optimal investment size for each building construction project.
According to the financial structure of the portfolio, project phasing can effectively improve the reinvestment strategy since it can reduce the investment size for each project and produce liquidity at an earlier time. For more information, the phasing approach can lead a potential project to be accepted or rejected partly or entirely; moreover, interruptions can occur temporarily or permanently in the project's implementation process. Based on this, semi-completed operable parts of the projects can generate profit; therefore, the firm's cash position and reinvestment strategy will be improved. Besides, opportunity costs of the idle assets of uncompleted projects' parts will be omitted (Li *et al.*, 2016; Shafahi & Haghani, 2018b; Zhong *et al.*, 2019).
Building projects can be divided into levels (Zhao & Tseng, 2003). For instance, consider a predefined building construction project of 3 levels within a portfolio. Figure 1 depicts possible phasing patterns of the project.

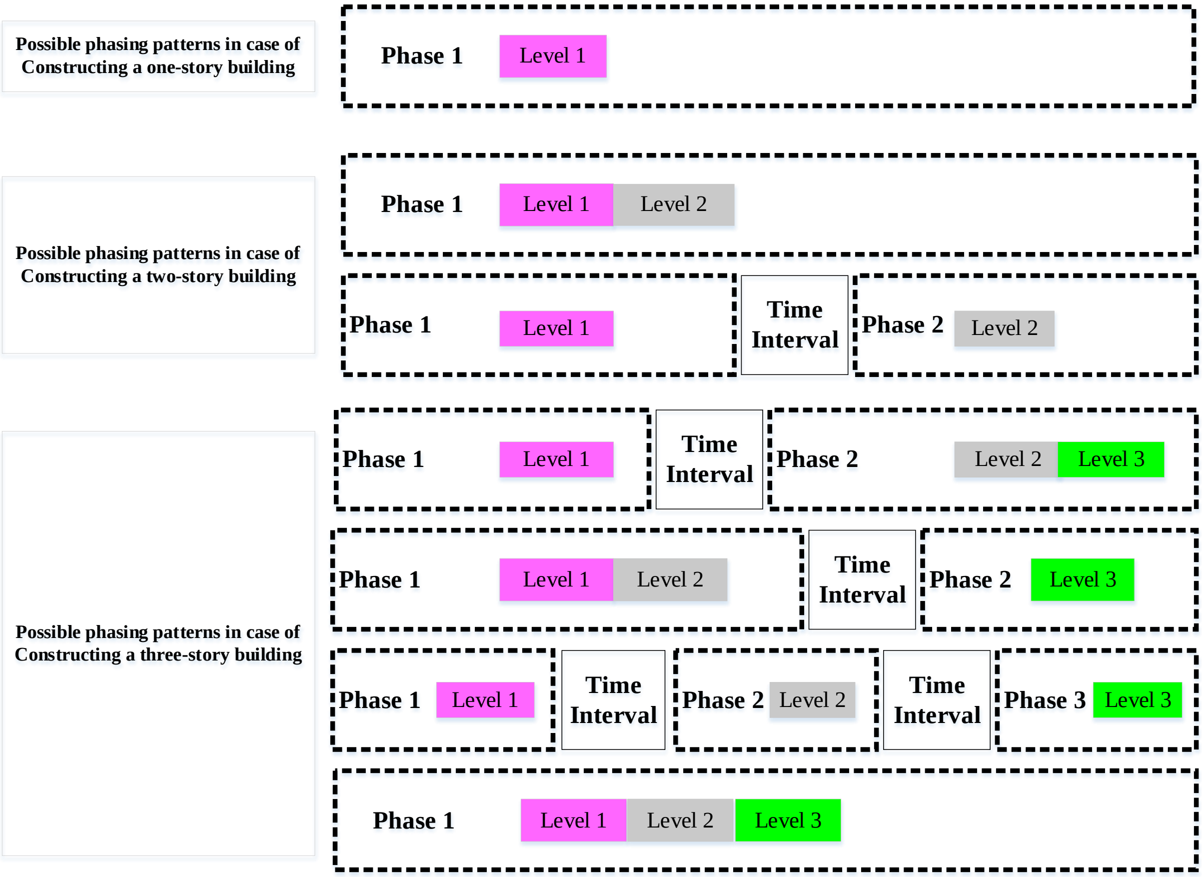

Figure1: Possible phasing patterns for a predefined three-story building construction project within a portfolio

According to figure 1, there are seven possible phasing scenarios for constructing a predefined three-story building project. In this context, the phasing strategy brings about entirely or partly complete scenarios for the scheduler; moreover, the implementation process can be either continuous or discontinuous.

It should be noted that the duration of each selected phase can vary according to financial constraints.

To model the phasing capability, the maximum height (maximum investing size) for each building construction project (v) is determined based on the maximum number of constructible floors (L_v); therefore, the optimum number of stories out of the predefined maximum number should be chosen In other words, each selected project can be accepted partly or entirely. In line with this, the possible executive modes (m) are defined per the number of floors, and the optimal estate will be obtained after solving. For instance, the first execution mode of project v is the one-story construction of project v, and so on for the other modes, up to defining project v entirely ($m = L_v$). For instance, the implementation modes of the example mentioned above in figure 1 are illustrated in figure 2.

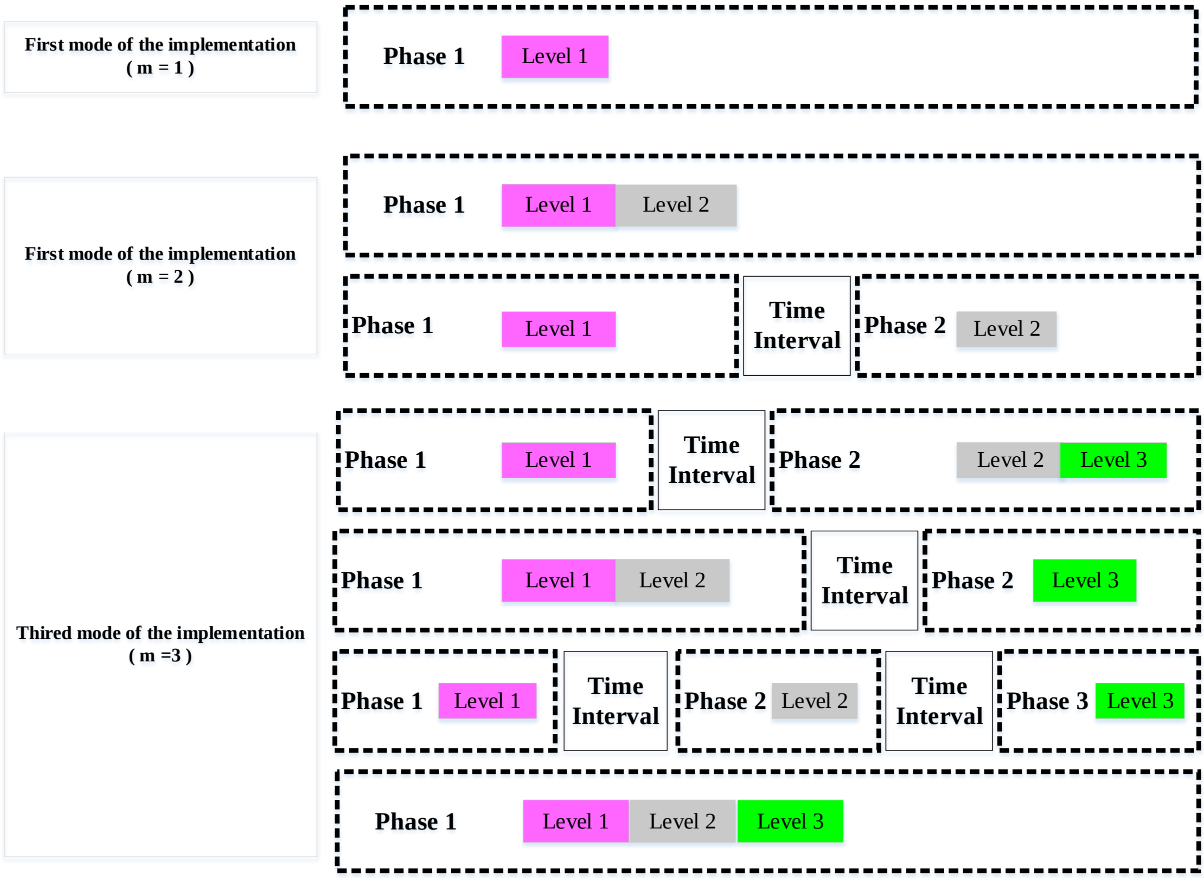

Figure 2: possible implementation modes for a predefined three-story building construction project within a portfolio.

For each execution mode m of the project v, there are some finish-to-start precedence relations between activities i and j (set E_{vm}); moreover, each activity j can generate income.

Executing each of the building components consumes resources. In this case, each resource r, defined in set Q ($r \in Q$), C_{jvmr} represents the total cost of resource r needed for execution of the activity j of the project v, which performs on mode m.

Mathematical Formulation

Sets and indicates:

V	Set of projects ($v \in V$).
J_{vm}	Set of activities of the project v, which has m stories ($j \in J_{vm}$).
E_{vm}	Set of prerequisites relation of the activities of the project v, which has m levels.
Q	Set of resources ($r \in Q$).

Parameters:

d_{jvm}	Duration of activity j of project v, in the case of implementing m stories for project v.
In_{jvm}	Income of the activity j of the project v, in the case of implementing m stories for project v.
C_{jvmr}	Cost of the resource r of the activity j of the project v, in the case of implementing m stories for project v.
α	Money discount rate.
P	Initial investment.
T_f	End time of the portfolio.
L_v	The maximum number of stories of the project v.

Decision variable:

x_{jvmt}	$\begin{cases} 1 & \text{if the activity j of the project v is selected at the time frame t} \\ 0 & \text{Otherwise} \end{cases}$
TC_r	The total cost of the resource r at the entire project portfolio.
$CPVI_t$	Net present value of the incomes in time ranges zero to t.
$CPVC_t$ α	Net present value of the costs in time ranges from zero to t.
St_{jvm}	Initial time of the activity j of the project v, in the case of implementing m stories for the project v.

Mathematical model

$$MaxF = P + CPVI_{T_f} - CPVC_{T_f} \tag{1}$$

Subject to:

$$\sum_{t=0}^{T_f} x_{jvmt} \le 1 \qquad (\forall m \le L_v \ \& \forall j \in J_{vm} \ \& \forall v \in V) \tag{2}$$

$$\sum_{t=0}^{T_f} x_{1vmt} \leq 1 \qquad (\forall m \leq L_v \ \& \forall v \in V) \qquad (3)$$

$$St_{jvm} = \sum_{t=0}^{T_f} t x_{jvmt} \qquad (\forall m \leq L_v \ \& \forall j \in J_{vm} \ \& \forall v \in V) \qquad (4)$$

$$St_{jvm} \geq (St_{ivm} + d_{ivm}) \sum_{t=0}^{T_f} x_{jvmt} \qquad (\forall v \in V \ \& \forall m \leq L_v \ \forall (i,j) \in E_{vm}) \qquad (5)$$

$$TC_r = \sum_{v \in V} \sum_{m=0}^{L_v} \sum_{j \in J_{vm}} \sum_{t=0}^{T_f} C_{jvmr} x_{jvmk} \qquad (\forall r \in Q) \qquad (6)$$

$$CPVI_t = \sum_{v \in V} \sum_{m=0}^{L_v} \sum_{j \in J_{vm}} \sum_{k=0}^{t} \frac{In_{jvm} x_{jvmk}}{(1+\alpha)^{k+d_{ivm}}} \qquad (t \in \{0,...,T_f\}) \qquad (7)$$

$$CPVC_t = \sum_{r \in Q} \sum_{v \in V} \sum_{m=0}^{L_v} \sum_{j \in J_{vm}} \sum_{k=0}^{t} \frac{C_{jvmr} x_{jvmk}}{(1+\alpha)^{k}} \qquad (t \in \{0,...,T_f\}) \qquad (8)$$

$$\sum_{v \in V} \sum_{m=0}^{L_v} \sum_{j \in J_{vm}} \sum_{k=0}^{t-d_{jvm}} In_{jvm} x_{jvmk} + P \geq \sum_{r \in Q} \sum_{v \in V} \sum_{m=0}^{L_v} \sum_{j \in J_{vm}} \sum_{k=0}^{t} C_{jvmr} x_{jvmk} \qquad (t \in \{0,...,T_f\}) \qquad (9)$$

$$G_{s_r}^r, x_{jvmt} \in \{0,1\}, \forall j \in J_{vm}, \forall v \in V, t \in \{0,...,T_f\}, s_r \in \square \qquad CPVI_t, CPVC_t \geq 0 \qquad (10)$$

In the above model, the objective function maximizes the investment's net present value. This function subtracts the present value of all revenues obtained from the implementation of the selected activities within the portfolios $(CPVI_t)$ from the present value of their costs up to time t $(CPVC_t)$ and finds the optimum value of this math operation.

Restriction (2) selects activities for projects in the project portfolio. If x_{jvmt} equals one, then the activity *j* of the mode m is selected within the portfolio at the time point *t*; otherwise, it will not be selected. In the case of selecting project v, restriction (3) emphasizes selecting just one mode of project v. Restriction (4) calculates the start time of the activities in the project portfolio, where x_{jvmt} equals one at time *t*; therefore, the quantity of tx_{jvmt} reveals the start time of the activity *j* which performs on mode m of the project v. Restriction (5) controls the prerequisites' relationships between the activities of the projects, and restriction (6) estimates the total cost of resource r. By considering the time value of money, restriction (7) calculates the present revenue value at any time interval *k.* Besides, regarding the time value of money restriction (8) calculates the current value of the cost of resources of the selected activities. The 9th restriction controls the self-financing financial structure of the project portfolio, in which the total cash in, including the initial investment plus the reinvestments up to time frame *k*, should not be less than the total cost of the selected activities up to time frame *k*. Finally, restriction (10) defines the model parameters.
In this article and the numerical example section, we have used GAMS software to obtain the final model answer.

Case example

Assume a property developer will work with three different sub-contractors, A, B, and C, to construct three building projects. Furthermore, each sub-contractor should provide all needed resources under the project program. In this case, each developer can benefit from the resource cost discount based on the total price of assigned executive activities to each sub-contractor.

The project portfolio consists of three three-story buildings and two two-story buildings. Precedence relationships and additional input data are shown in figure 3 and table 2, respectively. The portfolio time is assumed to be 18 months, and the time value of capital at a monthly discount rate is estimated to be 0.1%. The project portfolio should be managed with the initial capital of 145 thousand dollars self-reliantly.

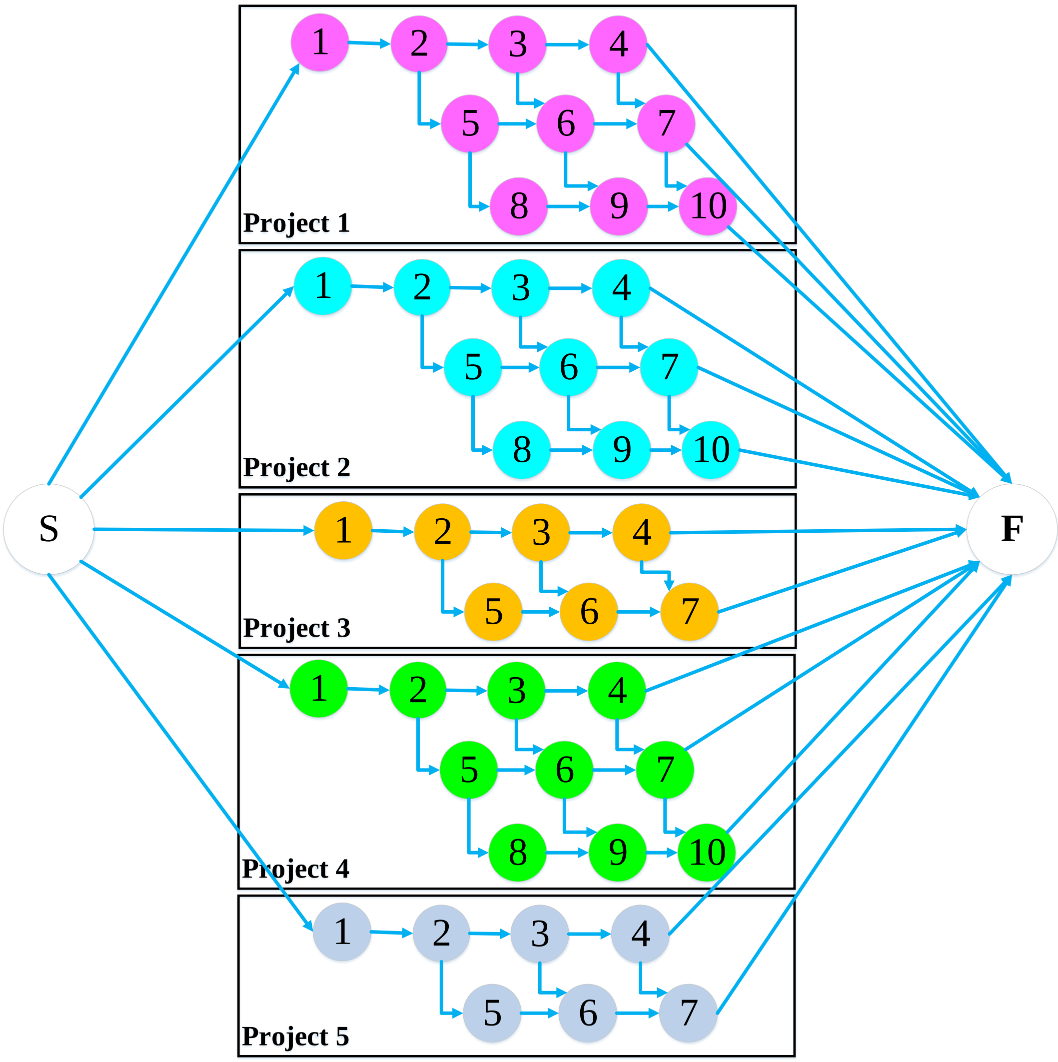

Figure 3: Precedence relation graph of the case example.

Table 2. Input data of the case example

No	activity	Project Number	Activity Number	Executive Mode	Duration (months)	Resource cost (Thousand dollars)			Income (Thousand dollars)
						A	B	C	
1	Foundation, Frame, Floors & surrounding walls for one-story building construction.	1	1	1	1	35			
2	First fix, Façade & so on. for one-story building construction.	1	2	1	1		15		
3	MEP for one-story building construction.	1	3	1	1			20	
4	Second fix & Finishing for one-story building construction.	1	4	1	1		15		93
5	Foundation, Frame, Floors & surrounding walls for two-story building construction.	1	1	2	2	56			
6	First fix, Façade & so on. for the first level of two-story building construction.	1	2	2	1		15		
7	MEP for the first level of the two-story building construction.	1	3	2	2			22	
8	Second fix & Finishing for the first level of the two-story building construction.	1	4	2	1		15		93
9	First fix, Façade & so on. for the second level of the two-story building construction.	1	5	2	2		15		
10	MEP for the second level of the two-story building construction.	1	6	2	1			22	
11	Second fix & Finishing for the second level of the two-story building construction.	1	7	2	1		15		103
12	Foundation, Frame, Floors & surrounding walls for three-story building construction.	1	1	3	2	63			
13	First fix, Façade & so on. for the first level of three-story building construction.	1	2	3	1		15		
14	MEP for the first level of the three-story building construction.	1	3	3	2			24	
15	Second fix & Finishing for the first level of the three-story building construction.	1	4	3	1		15		93
16	First fix, Façade & so on. for the second level of the three-story building construction.	1	5	3	2		15		

17	MEP for the second level of the three-story building construction.	1	6	3	1			24	
18	Second fix & Finishing for the second level of the three-story building construction.	1	7	3	1		15		103
19	First fix, Façade & so on. for the third level of three-story building construction.	1	8	3	2		15		
20	MEP for the third level of the three-story building construction.	1	9	3	1			24	
21	Second fix & Finishing for the third level of the three-story building construction.	1	10	3	1		15		113
22	Foundation, Frame, Floors & surrounding walls for one-story building construction.	2	1	1	1	35			
23	First fix, Façade & so on. for one-story building construction.	2	2	1	1		15		
24	MEP for one-story building construction.	2	3	1	1			20	
25	Second fix & Finishing for one-story building construction.	2	4	1	1		15		60
26	Foundation, Frame, Floors & surrounding walls for two-story building construction.	2	1	2	2	56			
27	First fix, Façade & so on. for the first level of two-story building construction.	2	2	2	1		15		
28	MEP for the first level of the two-story building construction.	2	3	2	2			22	
29	Second fix & Finishing for the first level of the two-story building construction.	2	4	2	1		15		60
30	First fix, Façade & so on. for the second level of the two-story building construction.	2	5	2	1		15		
31	MEP for the second level of the two-story building construction.	2	6	2	1			22	
32	Second fix & Finishing for the second level of the two-story building construction.	2	7	2	1		15		120
33	Foundation, Frame, Floors & surrounding walls for three-story building construction.	2	1	3	2	63			
34	First fix, Façade & so on. for the first level of three-story building construction.	2	2	3	1		15		

35	MEP for the first level of the three-story building construction.	2	3	3	2			24	
36	Second fix & Finishing for the first level of the three-story building construction.	2	4	3	1		15		60
37	First fix, Façade & so on. for the second level of the three-story building construction.	2	5	3	2		15		
38	MEP for the second level of the three-story building construction.	2	6	3	1			24	
39	Second fix & Finishing for the second level of the three-story building construction.	2	7	3	1		15		90
40	First fix, Façade & so on. for the third level of three-story building construction.	2	8	3	2		15		
41	MEP for the third level of the three-story building construction.	2	9	3	1			24	
42	Second fix & Finishing for the third level of the three-story building construction.	2	10	3	1		15		130
43	Foundation, Frame, Floors & surrounding walls for one-story building construction.	3	1	1	2	40			
44	First fix, Façade & so on. for one-story building construction.	3	2	1	2		20		
45	MEP for one-story building construction.	3	3	1	1			25	
46	Second fix & Finishing for one-story building construction.	3	4	1	1		20		120
47	Foundation, Frame, Floors & surrounding walls for two-story building construction.	3	1	2	3	72			
48	First fix, Façade & so on. for the first level of two-story building construction.	3	2	2	2		20		
49	MEP for the first level of the two-story building construction.	3	3	2	2			27.5	
50	Second fix & Finishing for the first level of the two-story building construction.	3	4	2	1		20		142
51	First fix, Façade & so on. for the second level of the two-story building construction.	3	5	2	1		20		
52	MEP for the second level of the two-story building construction.	3	6	2	1			27.5	

53	Second fix & Finishing for the second level of the two-story building construction.	3	7	2	1		20		91
54	Foundation, Frame, Floors & surrounding walls for one-story building construction.	4	1	1	1	35			
55	First fix, Façade & so on. for one-story building construction.	4	2	1	1		15		
56	MEP for one-story building construction.	4	3	1	1			20	
57	Second fix & Finishing for one-story building construction.	4	4	1	1		15		93
58	Foundation, Frame, Floors & surrounding walls for two-story building construction.	4	1	2	2	56			
59	First fix, Façade & so on. for the first level of two-story building construction.	4	2	2	1		15		
60	MEP for the first level of the two-story building construction.	4	3	2	2			22	
61	Second fix & Finishing for the first level of the two-story building construction.	4	4	2	1		15		93
62	First fix, Façade & so on. for the second level of the two-story building construction.	4	5	2	1		15		
63	MEP for the second level of the two-story building construction.	4	6	2	1			22	
64	Second fix & Finishing for the second level of the two-story building construction.	4	7	2	1		15		90
65	Foundation, Frame, Floors & surrounding walls for three-story building construction.	4	1	3	2	63			
66	First fix, Façade & so on. for the first level of three-story building construction.	4	2	3	1		15		
67	MEP for the first level of the three-story building construction.	4	3	3	2			24	
68	Second fix & Finishing for the first level of the three-story building construction.	4	4	3	1		15		93
69	First fix, Façade & so on. for the second level of the three-story building construction.	4	5	3	2		15		
70	MEP for the second level of the three-story building construction.	4	6	3	1			24	

71	Second fix & Finishing for the second level of the three-story building construction.	4	7	3	1		15		90
72	First fix, Façade & so on. for the third level of three-story building construction.	4	8	3	2		15		
73	MEP for the third level of the three-story building construction.	4	9	3	1			24	
74	Second fix & Finishing for the third level of the three-story building construction.	4	10	3	1		15		77
75	Foundation, Frame, Floors & surrounding walls for one-story building construction.	5	1	1	2	40			
76	First fix, Façade & so on. for one-story building construction.	5	2	1	2		20		
77	MEP for one-story building construction.	5	3	1	1			25	
78	Second fix & Finishing for one-story building construction.	5	4	1	1		20		110
79	Foundation, Frame, Floors & surrounding walls for two-story building construction.	5	1	2	3	72			
80	First fix, Façade & so on. for the first level of two-story building construction.	5	2	2	2		20		
81	MEP for the first level of the two-story building construction.	5	3	2	2			27.5	
82	Second fix & Finishing for the first level of the two-story building construction.	5	4	2	1		20		110
83	First fix, Façade & so on. for the second level of the two-story building construction.	5	5	2	1		20		
84	MEP for the second level of the two-story building construction.	5	6	2	1			27.5	
85	Second fix & Finishing for the second level of the two-story building construction.	5	7	2	1		20		114

The problem has been solved in two cases: not considering and considering the economy of scale. As the answer to the first case illustrates, the optimal combination consists of projects in mode three of the first and second projects and the first executive mode of the tired project. The Gantt diagram of the scheduling of this case is shown in figure 4. Besides, in this case, the optimum value of the objective function equals 294.49 thousand dollars.

On the other hand, as the Gantt chart of figure 5 depicts, the consideration of the economy of scale leads to the selection of mode one of the fourth project. In this case, the objective function will reach the value of 314.63 thousand dollars. The detailed calculation of the two cases is shown in Tables 3 and 4.

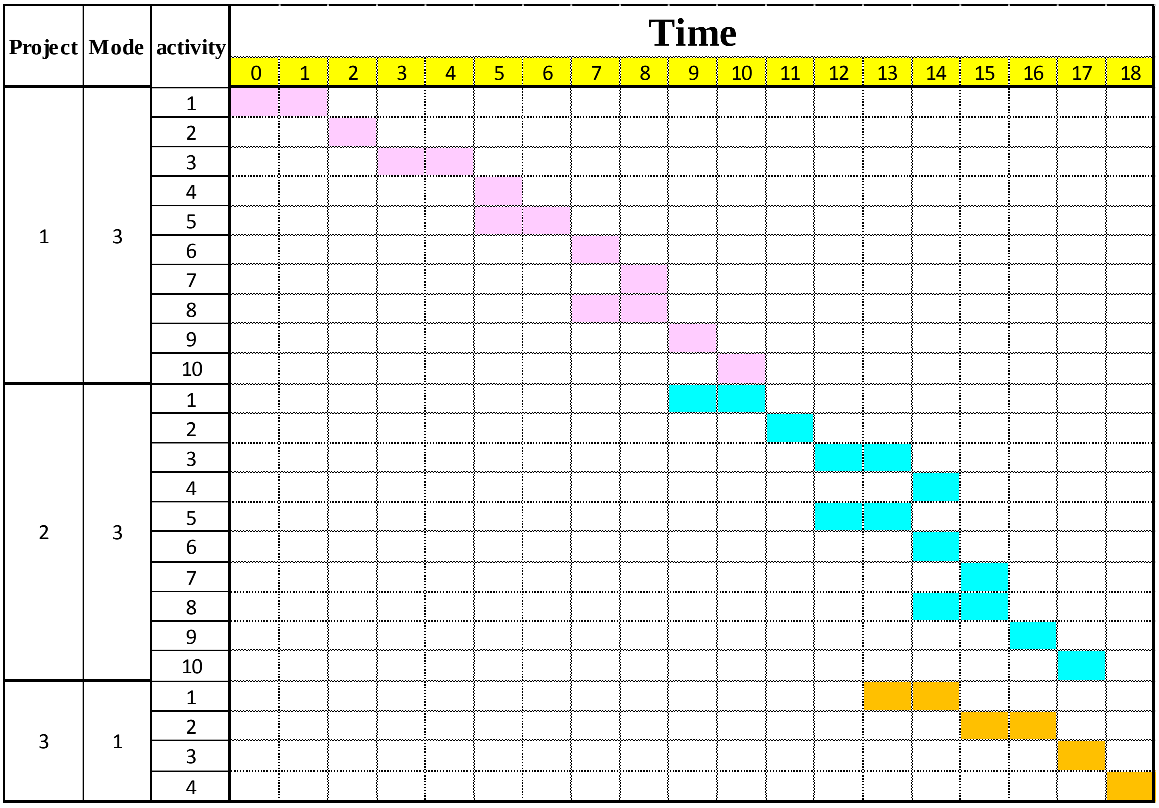

Figure 4: Gantt chart illustration of the optimal answer

Table 3. Detailed calculation of the optimal answer in the case of not considering the economy of scale (numbers are rounded up)

Time	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
TC_a	63	63	63	63	63	63	63	63	63	126	126	126	126	166	166	166	166	166	166	166
TC_b	0	0	15	15	15	45	45	60	75	75	90	105	120	120	150	185	185	200	220	220
TC_c	0	0	0	24	24	24	24	48	48	72	72	72	96	96	120	120	144	169	169	169
$CPVC_t$	63	63	78	102	102	132	132	171	186	273	288	303	342	382	436	471	495	535	555	555
$CPVI_t$	0	0	0	0	0	0	93	93	93	196	196	309	309	309	309	369	459	459	589	709
$Cash_t$	82	82	67	43	43	13	106	67	52	68	53	151	112	72	18	43	109	69	179	299
Objective function	82	82	67	43	43	13	106	67	52	68	53	150	111	72	19	43	108	69	177	294

Results show a favorable cash position at each time t ($Cash_t$), confirming the successful self-financing financial structure of the firm. In this case, potential liquidity generated by the smaller parts of the projects can be used for self-financing;

Activities of the first story of project one are executed as soon as possible; meanwhile, to lift financial constraints through reinvesting the proceeds of level one, the initiation of the other levels should be postponed for two time periods. In this case, liquidity is generated as soon as possible; therefore, the financial independence of the enterprise and self-financing capacity were improved; moreover, flexible scheduling of project one is provided.

In terms of the phasing strategy, the implementation process of projects three and four are interrupted permanently since their first modes are selected to be performed.

Conclusion

In terms of investment decisions, this article reveals a novel mathematical model for building construction project portfolios. Based on this, considering the phasing strategy and prerequisite relations among activities, the optimal selection and scheduling for the self-financing building construction project portfolio problem is proposed. The purpose is to maximize the net present value of the investment. Moreover, the presented model is mixed integer programming. From the managerial point of view, the proposed framework is beneficial since it entirely fits the fundamental nature of building construction project portfolios. In this context, the multi-stage repetitive process of implementing building construction projects in terms of the optimal phasing pattern of the building projects when organizing for development self-reliantly is presented. Hence, the proposed decision support tool can assist property developers in the real estate industry in developing decisions under financial constraints.

Future studies are recommended to integrate other financing strategies such as leasing, rental income, and loan strategy, in addition to considering resource allocation as well as multi-mode resource allocation.

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