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Continuous rescheduling optimization approach for successful real estate projects

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The economy of large-scale real estate projects (REPs) in Egypt is currently at risk. The increasing demand on residential, office buildings, retail, hotels and recreation as well as public services buildings has been encouraging investors from both private and public sectors to develop new compounds to meet this demand. These projects are huge in size and include several diversified functions and are usually implemented over many years. Real estate developers normally initiate their projects' master schedule at the early stage of their projects then, refine it every year. The construction of civil infrastructure utilities and networks usually takes place at the beginning of project implementation. This applies to all services such as water, electrical power supply, sewerage, telecom, natural gas and district cooling and heating. The infrastructure investment and construction decision is usually taken based on the ultimate capacity and feasibility studies that are based on the master schedule. Any changes during long-term implementation (which may be expected) might adversely affect infrastructure feasibility. This article aims at developing a model that would consider changes during project implementation and provide decision-makers with recommendations that would minimize the impact on their investment. The model functions through: (1) a central database containing data about real estate components such as function, gross built up area, construction cost and expenditure profile, cash-in profile and type (selling or renting), payment instalments by end users, etc.; (2) a scheduling module, which creates possible implementation scenarios based on certain constraints given to the model such as minimum and maximum allowable construction durations, as well as the construction time frame for the REPs; (3) a financial module, which calculates both cash-in, cash-out and projects' cash flow for the different scheduling scenarios; and (4) an optimization engine consisting of a genetic algorithm and a simulation module that compares all possible scheduling scenarios and defines which scenario best fits the objective function and maximizes the lifecycle net revenue. The model was implemented on a case study—a major real estate investment in New Cairo, where it proved to be an effective tool in providing decision-makers with different scenarios then recommending the one that minimizes the impact of changes realized on their investment.

Keywords: Infrastructure management, optimization, real estate development, rescheduling, strategic planning

Introduction

During the construction of large-scale developments, several external political, economic, marketing or social factors may dictate the real estate developers either to change their originally approved master schedules or at least to reschedule and relax their construction plans in order to mitigate marketing and financial risks. Recent political changes in different regions in the Middle East are examples of such risk.

This in turn has forced real estate developers to partially cancel the implementation of their scheduled projects or in better cases to reschedule and relax their projects construction schedules. As a result, cancelling or relaxing the developers' feasibility-based projects may hinder the feasibility of infrastructure projects that are constructed at the early stage prior to risk occurrence. The possible reduction in services demand may increase the services charges which are either transferred to end users as extra charges or incurred by the

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developers as financial losses. The resulting frustration between end users and developers would negatively affect investors' reputation and future sales from one side and users inconvenience on the other side.

The objective of this article is to introduce a novel approach/model to reschedule real estate projects (REPs) to achieve minimum negative impact on the feasibility of constructed utilities (infrastructure) in case of unforeseen risks are realized. The proposed model would consider the risks and support decision-makers in periodically rescheduling the implementation of the remaining work to achieve minimum impact on the constructed infrastructure systems profitability. The model represents a comprehensive yet easy application tool for optimum rescheduling of real estate development. Moreover, the model is capable of integrating the optimization of multiple infrastructure subsystems which shall enable supporting the decision-makers in rescheduling the remaining projects due to unforeseen risks by taking the lifecycle overall revenue as well as infrastructure systems profitability into consideration.

The developed model is applied on a large-scale REP in Egypt. The project is developed over 800 acres of land with a built up area of about 1.4 million square metres. The project has different functions that include offices, residential, hotels, retail and others. A central district cooling system, among other services is constructed to supply 30 000 tonne refrigerant to cool buildings inside the development. The capacity was defined based on consumption profiles at peak hours over project life and is based on a specific development schedule. The tariff was then calculated through a feasibility study initially prepared during early stage of the development. The market in Egypt has changed drastically due to recent political changes. This situation dictated the investors to relax their development schedule to avoid further financial losses. The model investigated the different scenarios resulting from the market changes and investor priorities and provided investor top management with a recommendation for phasing the remaining project work. Future research is currently going on to consider other subsystems of infrastructure and integrate them with the overall project feasibility.

Literature review

Real estate development usually demands extensive long-term investments. One of the primary characteristics of real estate is the presentation of entrepreneurs with numerous opportunities to generate extraordinary return (Pyhrr, 1989). During the pre-construction stage, developers must carefully assess possible development scenarios in order to fulfil certain objectives, such as product marketability, physical sustainability, financial feasibility and conformity to social and environmental space requirements. Previous research studies focused on preparing and assessing REPs at the pre-construction stage rather than developing pro-active concepts in monitoring the deviations of the risks during the construction phase. Pyhrr (1989) presented five levels of risk analysis that should be part of real estate investment decisions at early development stages. The five levels are basic feasibility model, discounted cash flow from most likely outcome, internal rate of return (IRR) partitioning and risk absorption analysis, sensitivity analysis and Monte Carlo simulation. Etter and Schmedemann (1995) categorized the risks incorporated in real estate investment into seven categories that relate to three main project characteristics as shown in Table 1.

(a) Physical immobility where real estate investment property cannot be removed, (b) long economic life where real estate investment property must produce cash returns over a long period in order to recover its cost and provide reasonable return to the investors and (c) large economic size where real estate investment in most cases requires large amount of capital investment as compared with other investments, i.e. common stock.

Models to support real estate decision-makers to prioritize projects fall under two main research areas: scheduling and portfolio selection. These models utilize simple ranking, based on certain evaluation criteria. Optimization is also used in scheduling and portfolio selection. Under portfolio selection (selecting projects for implementation), there are many research based on finding the criteria and then selecting and prioritizing projects according to these criteria (Elkashif *et al.*, 2005; Hosny *et al.*, 2007, 2011). Elkashif *et al.* (2005) categorized potable water public utility projects into six categories: uncompleted projects, politically enforced projects, maintenance projects, replacement projects, auxiliary projects and ordinary new projects. Projects are prioritized for implementation according to those categories. Hosny *et al.* (2011) developed a fuzzy multi-criteria decision-making model to help decision-makers in the selection of the optimum combination of potable water projects to be implemented under limited budget constraints. For schedule optimization many research to optimize schedules were conducted with various objectives such as minimizing the total cost, the project duration or monthly finance (Elazouni and Metwally, 2007; Hegazy and Elhakeem, 2011).

Several models were also developed to optimize the scheduling process in other industries (i.e. transportation and manufacturing). Zegordi and Beheshti Nia (2009) developed a model for the integration of

Table 1 Real estate investment risks, Etter and Schmedemann (1995)

Risks	Description	Main characteristics of REPs
(1) Business	The property will fail to generate sufficient cash flow	Physical immobility and long economic life
(2) Management	The property manager will fail to respond properly to changes in the business environment and, therefore, fail to earn a satisfactory return	Physical immobility and long economic life
(3) Financial	The property will have inadequate income to meet debt service requirements	Physical immobility, long economic life and large economic size
(4) Political	A government action adversely affects the property or the investor	Physical immobility and long economic life
(5) Inflation	Cash benefits received in the future will have less purchasing power than an equal benefit received today	Large economic size
(6) Liquidity	A property cannot be sold quickly without loss or large selling expenses	Physical immobility and large economic life
(7) Interest rate	The property's value will decrease because of increased interest rate	Long economic life and large economic size

production and transportation scheduling in a two-stage supply chain environment. The model used a mix of integer programming and genetic algorithm (GA) optimization model with the objective function of minimizing the total tardiness and total deviations of suppliers' assigned workloads. Tormos *et al.* (2008) developed a GA model for railway scheduling problem. The objective was to develop a timetable that would optimize train operations. Andre *et al.* (2009) developed solving techniques for minimizing investment costs on a gas transportation network by finding the optimal location of pipeline segments to be reinforced and their optimal sizes (among a discrete commercial list of diameters) under the constraint of satisfaction of demands with pressure enough for all users.

Wang (2010) introduced a two-stage real estate development project portfolio selection and scheduling decision-making system that can select groups of projects by maximizing profits and minimizing risk. He has also considered minimizing the value of cumulative net cash flow and minimizing the value of breakeven time of cumulated net cash flow to assist developers' decision-makers to implement optimal capital resource allocation. However, the model has not considered the infrastructure projects that are usually implemented at early stages of development and prior to risk occurrence. Leelarasamee (2005) claims that though decision-making systems are proven to be useful, they ignore several risks. Dzeng and Lee (2007) developed a model that used GA in the optimization of the development of resort projects. GA has been implemented through a model which is used to develop an optimized schedule for the amenities of the resort considering both the costs and revenues net present value which was taken as an objective function to be maximized. This model integrates simulation and GA for obtaining such development schedule.

Problem definition and solution approach

This research relies mainly on three realities which highlight the problem and the solution approach, as follows:

(1) REPs are usually long-term implementation projects. Accordingly, it is expected that, the accuracy of their plans varies from one implementation stage to another. Projects planned to be implemented in early stages (i.e. the infrastructure to serve the rest of REPs) are expected to follow the original feasibility-based schedule by acceptable margins. However, the later stages (mainly the REPs implementation) are expected to deviate from the original feasibility due to the fact that more unforeseen risks may occur during the lengthy implementation.

(2) At the sensitive points where risks occur due to the progressive elaboration nature of REPs, decision-makers usually react by cancelling or at least relaxing the implementation of remaining projects (REPs). These acts would apparently respond to the market risks and may mitigate financial risks but in turn, such a strategy will negatively affect the pre-development infrastructure and their feasibility. In addition, the relaxation would indeed affect the project lifecycle revenues. The underutilization of constructed infrastructure systems will increase its

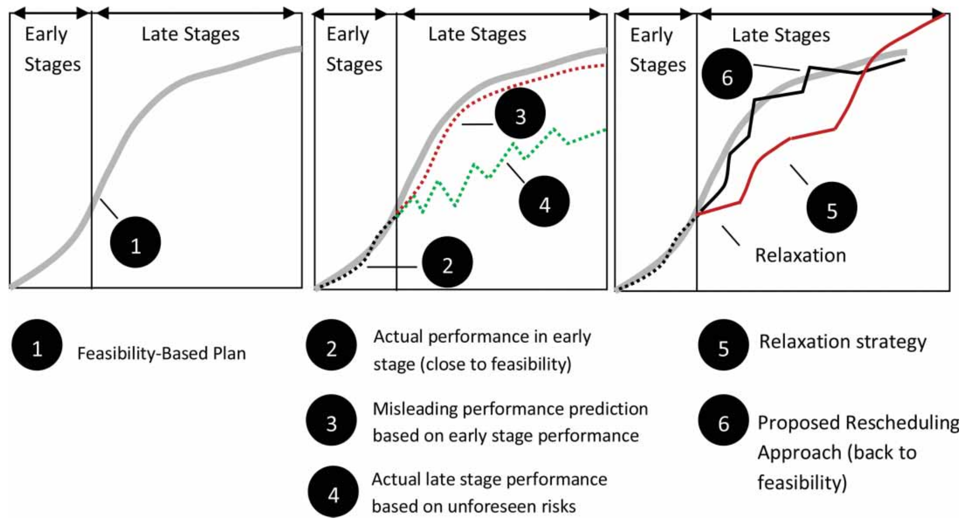

Figure 1 Problem illustration and proposed solution approach

unit cost, or the service tariff as its lifecycle production capacity would decrease. This increase in the service charges is either transferred to the end users or incurred by the developers as financial losses. The created frustration between end users and developers would negatively affect investors' reputation and future sales from one side and users inconvenience on the other side.

(3) A balanced solution accordingly, should maintain the feasibility of already constructed facilities or infrastructure systems and consider new risks at the same time. The problem can be resolved by delaying the implementation of some projects that are expected to be highly affected by new expected risks and replace them by other projects that are already in the master plan but might be scheduled late and are not affected/ impacted by those new risks. The success of this process is dominated by the optimum selection of the projects to be implemented during a certain period, based on their least sensation to new risks and the ability to utilize the constructed infrastructure as planned in the feasibility. Such an approach of periodically shuffling the schedule will save the total allowable time of the project and accordingly minimize the impact on lifecycle revenues. More importantly, it will keep the service charges of constructed infrastructure systems within the original feasibility figures.

Based on the above realities, the researchers have set an approach for periodically rescheduling the remaining REPs (e.g. at a yearly base). The approach keeps track of the constructed projects and tries to reschedule the remaining REPs in a way to minimize the impact of risk on the whole REP. The lifecycle revenue, as well as the infrastructure services tariffs, is considered. This applies to all services such as water, electrical power supply, sewerage, telecommunication, natural gas and district cooling and heating. Figure 1 highlights the problem and shows the proposed approach in comparison to traditional relaxation strategy.

Need for optimization

Through the periodic application of the proposed approach, it provides alternating scheduling scenarios for executing the remaining projects. In order to understand how complex the model can be, imagine 60 REPs are remaining at a certain period, where each has only three possible starting months (one, two or three). The start for each project needs to be optimally determined. Possible scenarios are $(3)^{60}$ (i.e. 4.24E28), from which only few will represent balanced solutions. The real problem is even more challenging due to the fact that these projects are long-term projects that can reach 120 months (10 years). Such problems are combinatorial in nature where the increase in the number of projects will add to the complexity many folds. Accordingly exhaustive search cannot be used and there is a need for not only an optimization technique but alsoa non-traditional one. In this research, GA is used.

GA is mainly based on the concept of the survival of the fittest derived from the biological systems (Elbeltagi *et al.*, 2005). Each solution of a given problem is represented as a string called chromosome where each chromosome consists of several genes. These genes represent the variables for the optimization problem. The

GA procedure starts by creating a population of chromosomes (solutions). During the creation of the initial population, the genes in the chromosomes are set randomly within the variables' allowable values. The procedure evaluates these chromosomes by measuring their fitness against an objective function. To simulate the natural process of the survival of the fittest, the chromosomes allow exchanging their genes through mutation and crossover to generate new chromosomes for new generations. Any new chromosome is evaluated and replaces a weaker member in the initial population to allow the population to evolve and have better chances to produce better solutions. This process continues till a best-fit (near optimum) solution is generated. There are four main parameters which affect the performance of the GA: the number of generations, population size, mutation rate and crossover rate. A larger population size and a larger number of generations help in getting an optimum solution but increase the time needed for processing.

For implementation purposes, advanced spreadsheet modelling was used. The model replaces the optimization mathematical formulation and links between possible variables (start months and durations of remaining projects) and the objectives and constraints. The objective in this study is set to maximize the lifecycle revenues constrained to be within a slight deviation of feasibility figures for developed infrastructure.

Proposed framework/model for successful implementation of REPs

Framework main process

The main process of the proposed framework is shown in Figure 2. The master plan is normally produced by considering the three feasibility aspects: physical, social and financial. The plan can be divided into two main stages the early stage which covers the implementation of various infrastructure systems and the late stage at which various REPs are to be implemented. The master plan can then reflect the overall project cash flow (in and out) and financial status. The implementation of infrastructure projects and a few number of REPs progress usually as planned during early stages of their feasibility-based schedules. The framework proposes the feasibility-based schedule as the main reference or bench-mark while optimizing the process during the later stage implementation of REPs. However, risks arise usually while the construction of the early stage infrastructure and early REPs is approaching its completion. The optimization solution proposes a multi-modular model that is able to optimize the remaining REPs schedule under the condition that the overall lifecycle revenue is maximized. Additional conditions can also be respected such as the developer's financial capability and the infrastructure system lifecycle revenue. Consequently, close to planned end users' services charges can be approached.

Framework main modules and spreadsheet modelling

The framework consists of four main modules, as follows: (1) database module, (2) generalized scheduling module, (3) financial module and (4) optimization engine (Figure 3). As shown in the figure, the scheduling module receives information from the database module regarding the remaining projects to be scheduled. The database also provides information regarding the expected durations and their allowances for these projects. The schedule module starts creating an implementation plan (schedule) by assuming the start month and duration (variables to be determined) for each remaining project. The module also deduces other schedules based on the implementation schedule for expected payments and selling policies based on marketing strategies information in the database for different projects types. The financial module considers the different generated schedules and the cost information for construction and selling in the database to determine cash-in, cash-out and net cash flows in addition to the evaluation of various lifecycle infrastructure utilization figures. These figures and cash distribution represent the main objectives to be achieved and constraints to be respected. Finally, the optimization engine is responsible for achieving and respecting the problem objectives and constraints using a GA solver (EVOLVER). Details about these modules in conjunction to their spreadsheet modelling are provided in the following sections.

Database module

The database module includes the basic information of REPs (individual projects). The database covers three categories of information: (1) basic information about involved projects; (2) budgeting and marketing strategies (monetary data) and (3) infrastructure feasibility data. These basic information are mainly the land area, gross built up area, location code on the master plan and land use (residential, office buildings, retail, mixed use, hotel, public services,… etc.). These basic information are simply modelled using Excel as an extendable table as shown in Figure 4. The second category (the monetary data) includes information regarding the construction costs and marketing strategies of selling and leasing prices that are essential for the financial module.

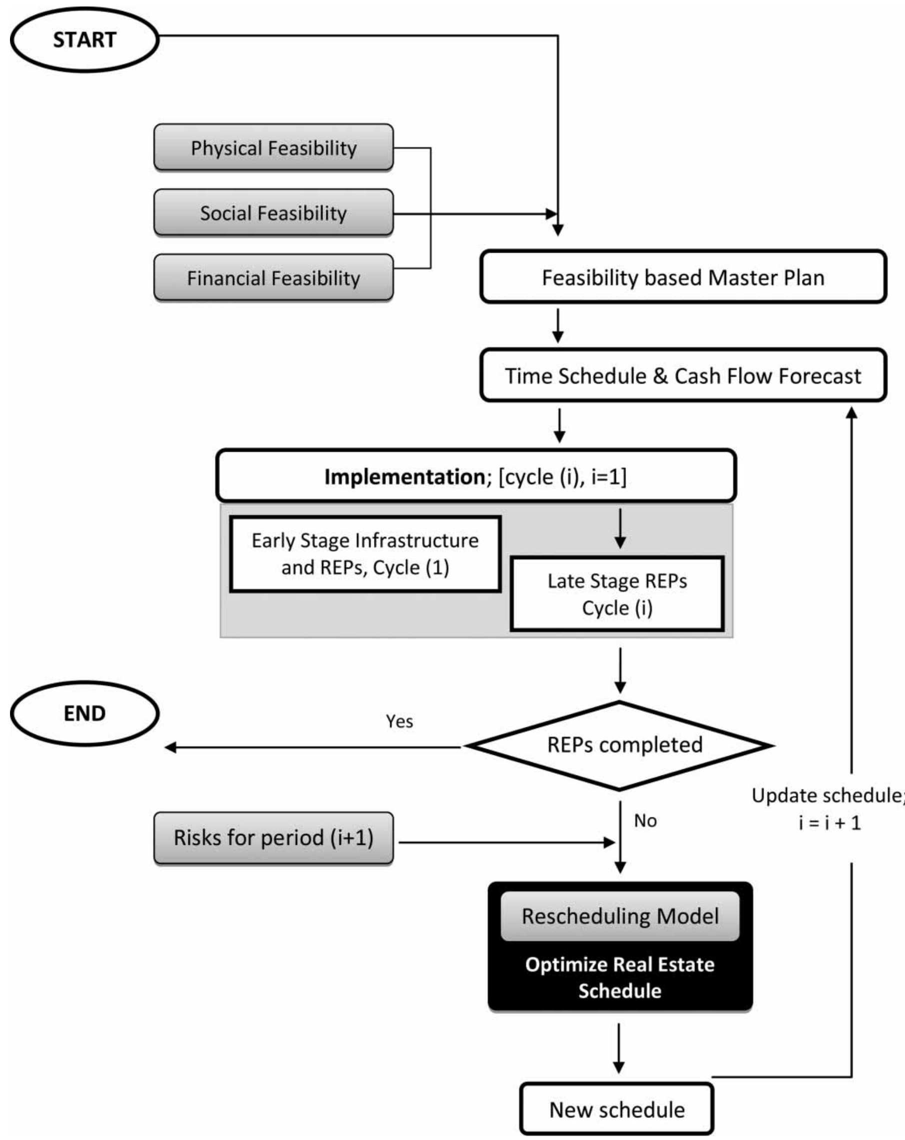

Figure 2 Proposed framework main process

The information helps in calculating the cash-out and cash-in by the help of the schedules obtained from the scheduling module. The monetary data are shown in Figure 5.

The third category is the infrastructure basic information which is summarized as follows.

District cooling demand

First, a technical district cooling simulation model was used by experts to define the demand depending on several factors, including the land use of each building (residential, retail, offices, etc.), its orientation, external wall thickness and insulation, glass types and thickness as well as the daily temperature profile and the season. The monthly district cooling demand is then extracted from the simulation and tabulated as part of the database as shown in Figure 6.

Potable water demand

The potable water is considered as a standard usage profile as per the local standard consumption. Figures are obtained from technical reports and used to define the daily demand in cubic metres of potable water depending on the building type (residential, retail, office buildings, etc.), as shown in Figure 7.

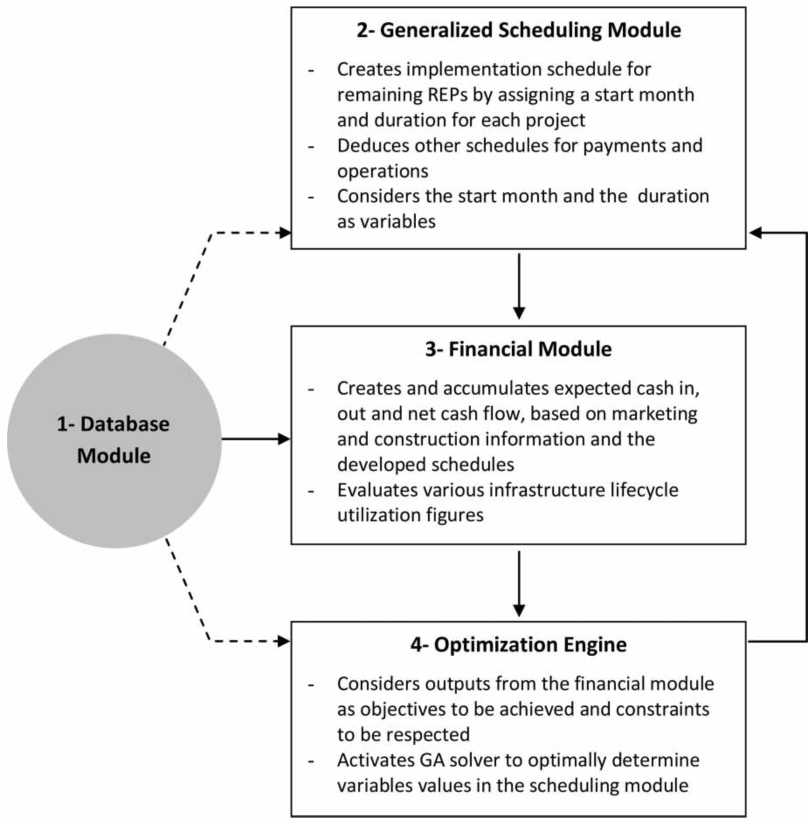

Figure 3 Framework main modules

Sewage demand

The demand is calculated as 85% of the potable water demand. Data are tabulated as shown in Figure 8.

Scheduling module

The scheduling module is a generic schedule model which is responsible for producing a set of schedules for projects' implementations, rentals and selling in addition to infrastructure utilization by each project. The possible schedules for each project are developed based on two variables; the construction duration of each project (Di) and the starting month of construction of each project (Xi). Accordingly the start and finish of project construction will be:

$$\mathrm{ST}i = Xi, \qquad (1)$$

$$\mathrm{FN}i = f(Xi,\ Di) = Xi + Di, \qquad (2)$$

where i refers to project number (i), the ST refers to the start date and the FN refers to the finish date.

Xi is used to define the starting month of project's construction (i) from the starting date of the whole development.

The implementation schedule is shown in Figure 9 with illustration of how to generate other schedules. It is worth to mention that the Di and Xi values for all projects are used by the optimization engine (explained here after) as decision variables during the optimization process. The Xi is a variable that defines when the construction of each project i can take place. The maximum allowed value of Xi is constrained by the latest date of completing the whole development. This constraint is dictated usually by local or national authorities in each country. The maximum allowed duration for developing large scale REPs is 10 years to count from the date of obtaining the ministerial decree, or approving the real estate development master plan. The Xi counts from the approval point in time.

The Di variable value refers, as explained above, to the project construction duration, with the start and end dates following Equations (1) and (2) above. The variable changes within a range of durations that are realistic in the construction world, e.g. between 16 and 36 months.

The scheduling module uses an intelligent binary representation in its spreadsheet modelling, to determine the bars using zero and one where one is used corresponding to scheduling times (e.g. under the red bars in Figure 9) and zero otherwise. The Excel conditional feature, zero cells will appear transparent while the one

#	Parcel & plot no.	Plot No.	Land use	GBA (m2)	Foot print area (m2)
NA	O (Villas - No DC)	O3	Life Style	249,131	488,544
1	B, L, M, F, J	O5b	Residential	23,294	8,627
2	B, L, M, F, J	O5d	Residential	23,898	8,851
3	B, L, M, F, J	O6a01	Residential	22,925	10,188
4	B, L, M, F, J	O6a02	Residential	14,036	5,198
5	B, L, M, F, J	O6a03	Residential	13,339	4,940
6	B, L, M, F, J	O6a04	Residential	13,016	4,820
7	B, L, M, F, J	O6a05	Residential	18,362	10,195
8	B, L, M, F, J	08	Residential	130,362	72,423
9	B, L, M, F, J	O5a01	Residential	13,301	4,926
10	B, L, M, F, J	O5a02	Residential	10,543	3,904
11	B, L, M, F, J	O5a03	Residential	12,866	4,766
12	B, L, M, F, J	O5e01	Mixed use (Res.)	7,123	3,957
13	B, L, M, F, J		Mixed use (Retail)		3,957
14	B, L, M, F, J	O5f01	Mixed use (Res.)	7,577	4,209
15	B, L, M, F, J		Mixed use (Retail)		4,209
16	B, L, M, F, J		Mixed use (Res.)		2,576

Figure 4 Database module (basic information)

		Construction cost	(Rent/Sell) price	
		EGP per m2	Rent (EGP/m2/month)	Sell (EGP/m2)
	Residential	6000	0	12,000
	Mixed use Retail	3000	120	0
	Mixed use Residential	4000	0	12,000
	Show rooms / Retail	3000	120	0
	Offices	5000	120	0
	Hotel	8000	100	0
	Mosque	1000	0	0
	Public services	1500	0	0
	Health care	7000	1500	0
	Recreation	4500	1500	0
	Patrol station	2500	1500	0
	Education	2500	150	0

Figure 5 Database module (monetary information)

District cooling Consumption
in TRH/month

	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Residential	1,049,244	1,093,505	1,483,547	1,442,760	1,521,423	1,530,561	1,593,445	1,614,222	1,488,090	1,502,562	1,334,953	1,129,956
Office	2,489,735	2,248,793	3,668,813	3,455,230	3,670,350	3,615,427	3,762,652	3,830,362	3,593,036	3,668,024	3,362,127	2,681,253
Hotel	162,619	169,478	253,299	243,880	255,771	248,612	252,171	250,182	238,680	241,585	234,728	175,128
Retail	2,707,327	2,821,532	3,894,106	3,936,332	4,147,123	4,146,550	4,287,808	4,165,118	4,064,855	4,133,406	3,860,054	2,915,583
Mixed use	331,963	345,966	473,602	470,321	494,636	510,956	522,869	510,712	495,515	490,237	445,476	357,499
Show rooms	275,220	286,830	333,146	292,485	334,408	354,368	382,180	423,415	338,384	318,952	241,397	296,391

Figure 6 Database module (district cooling demand)

	consumption (m3/m2 GBA/day)
Villas	0.00065
Residential	0.018
Office	0.0035
Hotel	0.0149
Retail	0.0042
Mixed use	0.0106
Show rooms	0.0019
Education	0.0025
civic	0.0208
patrol station	50

Figure 7 Database module (potable water demand)

cells' background will appear in a colour (red for example) to show the intelligent bar, or the project duration schedule. For example, if a project *i* is having *Xi* = 5 (starting at month 5) and *Di* = 3 (three months construction duration). Table 2 shows further these durations in the binary system.

This feature enables accumulating further display of expenditure, income, infrastructure utilization, … etc. on monthly basis.

Financial module

At the end of the process, the financial module generates the overall net revenue, cash-out, cash-in, the net cash flow profiles and the infrastructure utilization as functions of *Xi* and *Di*. Any change in the starting month of each project *i* and/or its construction duration *Di* will lead to a change in the mentioned generated figures and profiles. In this article, the objective function of the optimization problem is to maximize the overall lifecycle revenue represented by the net present worth (NPW). This can be obtained by changing the set of *Xi* and *Di* for each project. Besides the NPW, both the IRR and the pay back period can also be calculated from the resulting lifecycle cash flow profiles as the objective function can be changed to either maximization or minimization of a factor or the other. The effect of inflation or other financial impacts of risks can also be reflected easily in the module if the risk is resulting in such impacts. Detailed calculations depend mainly on the produced schedules provided by the schedule module. The cash-out is calculated using the implementation schedule after loading it with the construction costs of each project. In this article, the construction cost distribution over the project duration is considered following the normal distribution that results in cumulative S-shaped expenses curves.

The cash-in calculation depends on the renting and selling schedules. Once a project is scheduled for construction, its renting or selling schedule can be determined and used to determine the expected cash-in according to the pre-specified marketing strategy. Finally, the net cash flow is calculated (Figure 10).

The infrastructure demand and monthly demands are calculated using the infrastructure utilization schedule. It is assumed that the consumption starts one month after the delivery of the unit to the end user (Figure 11).

Optimization engine

The three aforementioned modules form one dynamic platform model at which many inputs are dynamically

Plot No.	% of GBA	DC consumption (TRH)												potable water (m3/25 years)	Sewerage system (m3/25 years)
O3		1	2	3	4	5	6	7	8	9	10	11	12	1488334	1265084
O5b	0.08	82,587	86,071	116,772	113,562	119,753	120,473	125,422	127,058	117,130	118,269	105,076	88,940	3879518	3297590
O5d	0.08	84,729	88,303	119,800	116,506	122,858	123,596	128,674	130,352	120,167	121,335	107,801	91,247	3980111	3383095
O6a01	0.08	81,279	84,708	114,922	111,763	117,856	118,564	123,435	125,045	115,274	116,395	103,411	87,531	3818062	3245353
O6a02	0.05	49,764	51,863	70,362	68,428	72,158	72,592	75,574	76,560	70,577	71,264	63,314	53,592	2337637	1986991
O6a03	0.05	47,293	49,288	66,868	65,030	68,575	68,987	71,821	72,758	67,073	67,725	60,170	50,931	2221554	1888321
O6a04	0.04	46,147	48,094	65,249	63,455	66,915	67,316	70,082	70,996	65,449	66,085	58,713	49,697	2167760	1842596
O6a05	0.06	65,101	67,848	92,048	89,517	94,398	94,965	98,867	100,156	92,330	93,228	82,828	70,109	3058114	2599397
08	0.44	462,191	481,687	653,500	635,534	670,184	674,210	701,910	711,062	655,501	661,876	588,045	497,744	21711242	18454556
O5a01	0.04	47,158	49,147	66,677	64,844	68,380	68,790	71,617	72,551	66,882	67,532	59,999	50,785	2215226	1882942
O5a02	0.04	37,380	38,956	52,852	51,399	54,201	54,527	56,767	57,507	53,014	53,529	47,558	40,255	1755892	1492508
O5a03	0.04	45,616	47,540	64,497	62,724	66,143	66,541	69,275	70,178	64,694	65,324	58,037	49,125	2142778	1821361
O5e01	0.12	41,393	43,139	59,054	58,645	61,677	63,712	65,197	63,681	61,786	61,128	55,547	44,577	689581	586144
O5f01	0.13	44,031	45,889	62,818	62,383	65,608	67,773	69,353	67,740	65,725	65,025	59,087	47,418	733533	623503
O5c01	0.08	26,946	28,083	38,444	38,177	40,151	41,476	42,443	41,456	40,222	39,794	36,161	29,019	448910	381574
13a01	0.15	51,150	53,308	72,974	72,469	76,215	78,730	80,565	78,692	76,350	75,537	68,640	55,085	852126	724307
13a02	0.30	98,023	102,158	139,846	138,877	146,057	150,876	154,394	150,804	146,317	144,758	131,541	105,563	1632999	1388049

Figure 8 Database module (sewage demand)

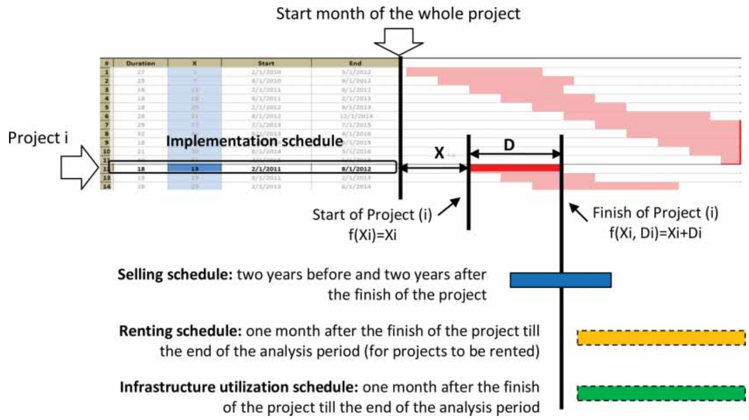

Figure 9 Scheduling module

Table 2 Project construction starting date and duration

Month no.	1	2	3	4	5	6	7	9	10	11	12	13	…… development end date
Project *i*	0	0	0	0	1	1	1	0	0	0	0	0	0

linked to outputs. This model is capable to conduct many analyses, sensitivity, simulation and optimization. The optimization represents one of the main research focuses; the last module is an optimization engine which functions on top of the developed model. EVOLVER™ V.5.5 add-in for Excel® is used, which suits the complexity of the problem in hand. The values of both variables *Xi* and *Di* represent the process variables as stated above. The changes in any of the variables changed the REPs implementation schedules accordingly. Other schedules, such as the renting or selling revenues, construction expenditure and infrastructure utilization will change accordingly resulting in a different lifecycle cash flow forecast. The NPW of the cash flow is thus linked to both variables *Xi* and *Di* through the step-by-step modelling process. The GA optimization engine searched for the optimized solution by comparing different scheduling scenarios corresponding to certain *Xi* and *Di*.

The module starts by calculating the lifecycle quantities of the services (district cooling, potable water and sewerage), then calculates the lifecycle revenue based on the feasibility-based tariffs as shown in Figure 11.

The optimization objective function is set to maximize the lifecycle net revenue that includes the cash flow from the financial module and expected infrastructure utilization as main constraints. The optimization/Evolver settings satisfy the following requirements (Figure 12):

	Total Cash out	Total Cash in
1/1/2010	EGP 21,428,571	EGP 0
2/1/2010	EGP 24,922,671	EGP 0
3/1/2010	EGP 24,922,671	EGP 0
4/1/2010	EGP 24,922,671	EGP 0
5/1/2010	EGP 24,922,671	EGP 27,952,800
6/1/2010	EGP 24,922,671	EGP 45,714,475
7/1/2010	EGP 24,922,671	EGP 3,785,275
8/1/2010	EGP 54,322,900	EGP 35,569,075
9/1/2010	EGP 54,322,900	EGP 84,442,631
10/1/2010	EGP 54,322,900	EGP 54,989,156
11/1/2010	EGP 54,322,900	EGP 11,972,756
12/1/2010	EGP 54,322,900	EGP 11,972,756
1/1/2011	EGP 79,312,525	EGP 11,972,756
2/1/2011	EGP 88,856,688	EGP 28,815,956
3/1/2011	EGP 88,856,688	EGP 39,518,406
4/1/2011	EGP 88,856,688	EGP 14,253,606
5/1/2011	EGP 110,514,363	EGP 14,253,606
6/1/2011	EGP 115,679,230	EGP 14,253,606
7/1/2011	EGP 115,679,230	EGP 14,253,606
8/1/2011	EGP 119,237,999	EGP 30,260,406
9/1/2011	EGP 119,237,999	EGP 40,431,394
10/1/2011	EGP 115,743,899	EGP 16,421,194
11/1/2011	EGP 115,743,899	EGP 16,421,194
12/1/2011	EGP 96,506,736	EGP 16,421,194
1/1/2012	EGP 100,198,461	EGP 16,421,194
2/1/2012	EGP 103,686,829	EGP 16,421,194
3/1/2012	EGP 82,029,154	EGP 16,421,194
4/1/2012	EGP 69,785,487	EGP 16,421,194
5/1/2012	EGP 72,256,137	EGP 44,373,994
6/1/2012	EGP 74,857,242	EGP 20,967,394
7/1/2012	EGP 33,270,595	EGP 23,856,125

Figure 10 Financial module

- Respecting the cash-out at any point in time at a certain level that matches the developer's financial capability.
- Respecting the lifecycle efficiency of infrastructure system at the same limit on which the original feasibility study was built. In other words, keeping the minimum lifecycle infrastructure services utilization as same as the feasibility-based quantity (for district cooling, water and sewerage). This utilization level is based on the original feasibility Tariffs.
- Considering a range of construction durations for each project in the optimization.

Case study: real estate development in Egypt

A 3 million square metres real estate development was selected to validate the proposed approach/model. The development is a visionary mixed use urban community located in new Cairo. Upon completion, the development will be home to over 13 000 residents in villas and apartments and a place to work for 50 000 office staff.

The project includes advanced and automatically controlled infrastructure systems that include

- 30 000 tonnes refrigeration generated by central district cooling facility;
- 5000 m^3 potable water underground storage tank and related pumping facility and network;
- 5000 m^3 underground irrigation tank and landscape irrigation network
- Natural gas system
- Telecom networks
- 66/22 electrical power substation and power supply grid.
- 12 000 m^3/day waste water treatment facility and sewerage network.

The master plan was developed several years ago and was approved by the authorities after compliance with local rules and regulations. The 3 million square metres real estate master plan includes 68 buildings of different functions (hospitality, residential, office buildings, show rooms, etc.). In addition, a lifestyle villas projects is located at the city as well. The district cooling is planned to serve most of the city buildings except for the villas that was found not feasible prior to construction and a number of operational buildings prior to commence construction, such as a school and two automotive show rooms. The development components and infrastructure utilities were proven feasible and hence allowed to start construction.

The construction of the development has started in January 2010. The first batch of projects included all the infrastructure projects listed above as well as a number of office buildings, show rooms and retail mall. The construction was progressing very fast due to the governmental pressure to complete the development construction in compliance with local dictated development deadlines and local land ownership regulations. However, in January 2011, the local unrest and uncertainty in Egypt has caused interruption to construction activities and plans. Besides, the real estate market has slow down and dictated the developers to relax their programmes awaiting an improvement in the political situation. Hence, the development is challenged by a situation where a nearly completed infrastructure systems is realized while the market is dramatically changing and may not allow for selling or leasing the units which is considered as major deviation to the feasibility original plans.

The above situation represents a clear case where a need is created to reschedule the construction plan so that a minimum interruption would hinder the original projects feasibility based on which the infrastructure services charges were calculated. The unrest in the Egyptian situation may cause similar effects to those resulting from other risks not only in the developing countries but in developed countries as well such as market financial recessions, unpredictable changes in the real estate market demands.

The input data were discussed in Section 4—'Proposed framework'. Results are in the following section.

	Total Life Cycle quantities	Min quantity (Feasibility-based quantity)	Max Quantity (System Capacity)	Tarrif EGP	Total services revenue over 25 years in EGP	Min amount in EGP	Max amount in EGP
DC	1,944,471,166	1,994,351,157	5,475,000,000	1	1,944,471,166	1,994,351,157	5,475,000,000
Water	60,023,368	61,270,542	109,500,000	1.5	90,035,052	91,905,813	164,250,000
Sewer	51,019,863	52,079,961	93,075,000	1.05	53,570,856	54,683,959	97,728,750

Figure 11 Infrastructure lifecycle revenue (utilization)

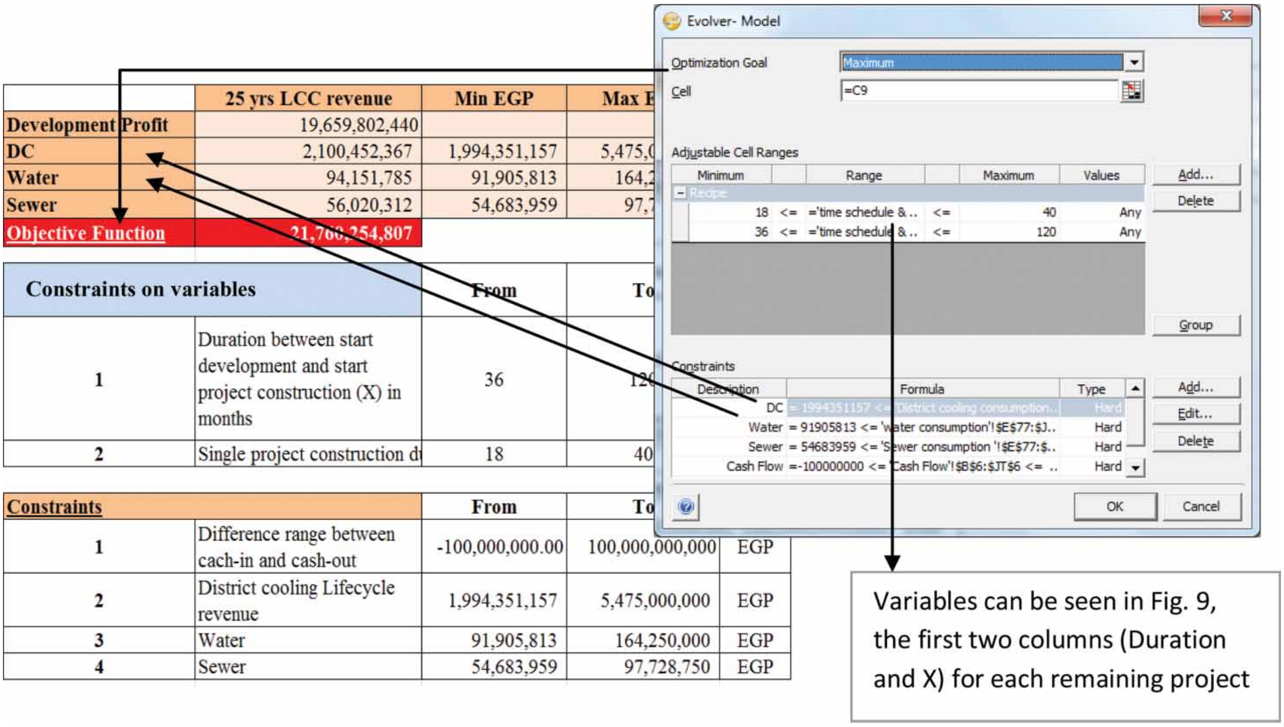

Figure 12 Optimization settings

Model run cases

The optimization model is applied partially to three infrastructure systems (potable water, district cooling and sewerage) only due to the limited available information. However, other services can follow in future research by applying the same concept to the optimization model. Table 4 shows the different assumptions and constraints, and Table 3 shows the model output for different given cases. The different cases are as follows.

Case (1): Feasibility-based case

The basic case schedule is the schedule based on which the development feasibility for REPs and infrastructure systems was prepared.

Case (2): Unrest case (or called revolution case)

All non-started projects at the Egyptian unrest event (1 January 2011) are rescheduled by delaying their start by 24 months from the date of unrest, which is 1 January 2011, or by 36 months from the whole development starting date which is 1 January 2010. Those projects started prior to 1 January 2011 shall continue until their construction completion. The maximum value of '*X*' is also increased by 36 months as compared with Case (1) or their starting date in the feasibility-based case.

Case (3): Optimization case

Similar to the unrest situation, all non-started projects at the Egyptian unrest event (1 January 2011) are delayed by 24 or 36 months from the whole development starting date (1 January 2010). Those project constructions started prior to 1 January 2011 shall continue until completion of construction. The maximum value of '*X*' is also increased by 36 months as compared with Case (1) or the feasibility-based case. The optimization model was run for four different situations. The assumptions and constraints in terms of durations and *X* values for the four runs are the same. The runs are:

First run: Optimization while fixing the infrastructure services lifecycle revenue as constraints in the model as well as the maximum allowable negative monthly cash flow.

Second run: Optimization while fixing the maximum allowable negative monthly cash flow as constraint but NOT fixing the infrastructure services lifecycle revenue in the model.

Third run: Optimization while NOT fixing the maximum allowable negative monthly cash flow NOR fixing the infrastructure services lifecycle revenue as constraints in the model.

Fourth run: Optimization while fixing the infrastructure services lifecycle revenue as constraint and NOT fixing the monthly minimum monthly cash flow as constraint.

It can be noted that the different cases represent a method for validating the model. The results, as discussed later, are changing in a logic manner in line with the changes made in the constraints in each of the cases.

Summary results

Table 3 and Figure 13 show the results obtained from the model either before or after optimization. The first optimized schedule run provided an improvement in the lifecycle overall revenue (combined for REPs and infrastructure services) as compared with the unrest schedule case. The revenue reduced by 3% as compared with the feasibility-based case versus 10% for the unrest case without optimization (Egyptian pounds (EGP) 21.1 billion versus EGP 19.7 billion for both cases, respectively, compared with EGP 21.8 billion for the feasibility-based case). All revenue items for the REPs and infrastructure services have improved and have reached levels above the feasibility-based case. The maximum negative cumulative cash flow almost has not changed at the level of EGP 1.6 billion for both cases which is acceptable if compared with the EGP 1.5 billion in the feasibility-based case (Table 4). Table 4 shows the results obtained from the model under consideration.

Table 3 Summary of the model constraints and assumptions for the different cases

	(1) Minimum lifecycle revenue (feasibility-based) (no optimization)	(2) Risk-based (unrest case) (no optimization)	(3) Optimization case			
			First run	Second run	Third run	Fourth run
X-value						
From	1	36	36	36	36	36
To	96	120	120	120	120	120
Individual project						
From	18	18	18	18	18	18
To	40	40	40	40	40	40
Infrastructure min lifecycle revenue as a constraint	No optimization	No optimization	Yes	No	No	Yes
Maximum negative monthly cash flow as a constraint	No optimization	No optimization	Yes	Yes	No	No

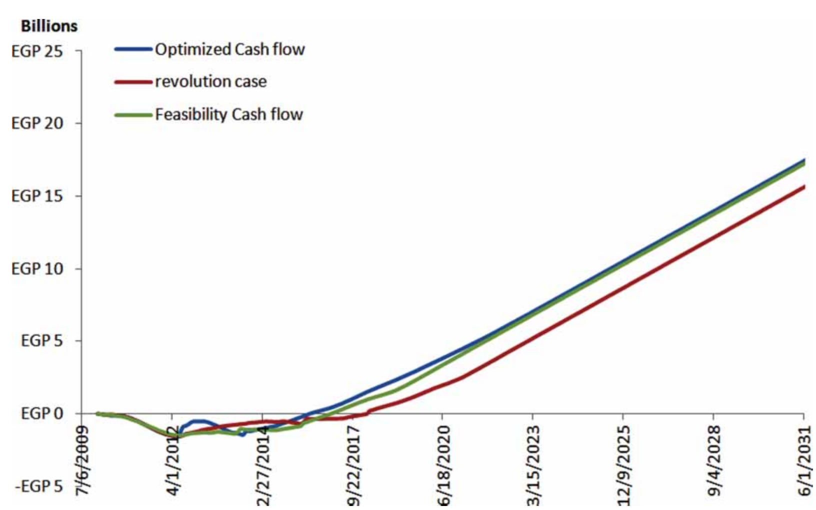

Figure 13 Cumulative cash flow curves: comparison between feasibility case scenario in green, the unrest case in red and the optimized first run in blue

Table 4 The model output in the different cases

Cases	(1) Feasibility-based minimum acceptable lifecycle revenue (no optimization)	(2) Risk-based (no optimization)	(3) Optimization cases First run	Second run	Third run	Fourth run
Lifecycle cumulative cash flow (in billions)	19.7	17.8	19.1	20.3	20.5	20.7
District cooling revenue (in billions)	1.99	1.94	2.0	2.1	2.1	2.2
Potable water revenue (in millions)	91.9	84.5	91.9	90.5	90.0	96.2
Sewerage revenue (in millions)	54.7	50.3	54.7	53.9	53.6	57.3
Total lifecycle cash flow (in billions)2	*21.8*	*19.7*	*21.1*	*22.4*	*22.6*	*22.9*
Maximum cumulative negative cash flow (in billions)	−1.5	−1.6	−1.6	−2.1	−2.1	−2.8
Maximum negative monthly cash flow (in millions)	−100	−100	−100	−100	Output: −130	Output: −170
Maximum negative cumulative cash flow (in billions)	−1.6	−1.6	−1.6	−2.1	−2.1	−2.8

Note: Amounts in EGP.

Although there are further improvements in the overall lifecycle revenue figures in the three remaining optimization runs (second, third and fourth) in the optimization case, the three cases have provided further increase in the maximum negative cumulative cash flow, which exceed the financial capability of the developer (EGP −2.1 billion, EGP −2.1 billion and EGP −2.8 billion) in the three cases as compared with the EGP −1.6 billion in the first optimization case which makes it a preferable option from the three sides:

(1) Better lifecycle overall revenue.
(2) Less cumulative negative cash flow as well as respecting the monthly maximum negative cash flow of EGP 100 million.
(3) Infrastructure services lifecycle revenues that are respecting the feasibility-based schedule case.

Therefore, the first run of the optimized schedule case is preferable as compared with the unrest optimized schedule case. The three schedules are shown in Figure 14. The three cases represent the application of sensitivity analysis given the two constrains: the maximum individual monthly cash-out or expenditure of EGP 100 million; and the maximum negative cumulative cash-out of EGP 1.6 billion. The lifecycle revenue in the second run of the optimization cases as shown in Table (3) has reached EGP 22.4 billion which is better than the originally feasibility-based figure of EGP 21.8 billion and the relaxed risk-based scenario with no optimization whose figure is EGP 19.7 billion. This improvement is reached by freeing the maximum lifecycle revenue of being a constraint. The improvement is even better in the third run where the cumulative amount of EGP 1.6 billion is not put as constraint. The lifecycle revenue has reached EGP 22.6 billion corresponding to a negative cumulative expenditure of EGP 2.1 billion. In the fourth run of the optimization cases, where the optimization was made without any constraints, i.e. neither maximum negative limit (EGP 100 million) nor maximum negative cumulative expenditure (EGP 1.6 billion). It has achieved an optimized schedule that improved the lifecycle revenue to EGP 22.9 billion which is better than any revenue that resulted from other cases.

The model was introduced to decision-makers of the real estate development where they revised the results of the different runs and found them logic and beneficial in analyzing the sensitivity of the output to the different constraints.

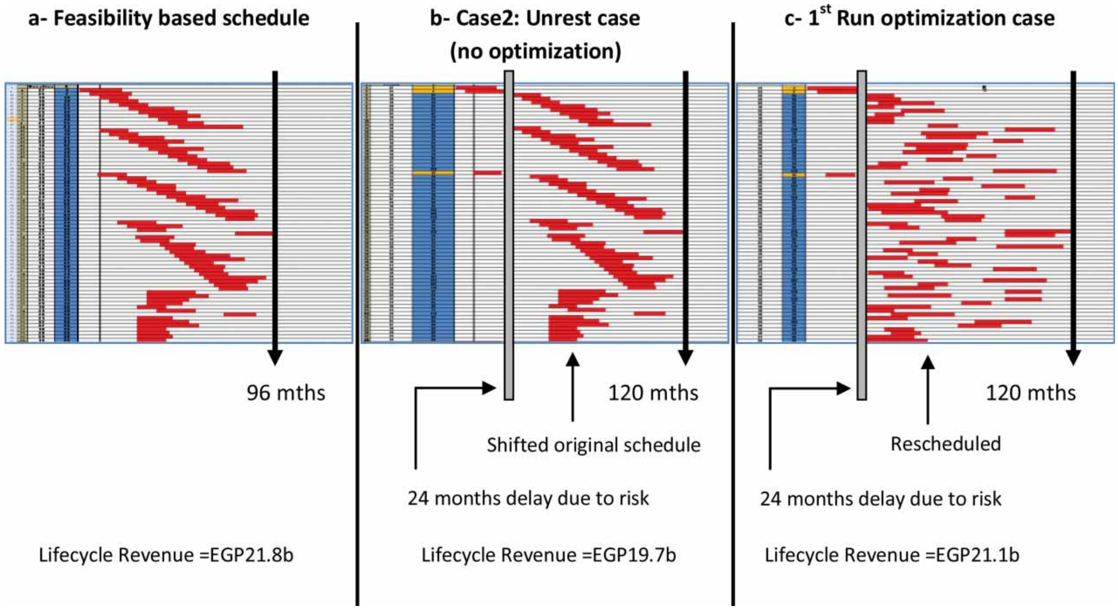

Figure 14 The three different schedule cases

Discussion and conclusions

This article presents the challenges facing the successful implementation of REPs in risky environments. In accordance with the stated aim of this article, the resulting model can be seen as a decision-making tool that provides recommendations to real estate development decision-makers. As discussed above, different optimization runs have provided optimized schedules of different project contained within the real estate development. The resulting schedules provide better lifecycle revenues for the development as a whole. Decision-makers can thus use the model as a framework/model periodically to reschedule their remaining REPs to minimize risks and support their decisions in achieving minimum impact on constructed infrastructure systems profitability. The model represents a comprehensive yet easy application tool for optimum rescheduling of real estate development. It is comprised of four main modules: a database module, a generic scheduling module, a financial module and an optimization engine. The model is capable of integrating the optimization of multiple infrastructure subsystems which shall enable supporting decision-makers in rescheduling the remaining projects whenever unforeseen risks arise by taking the lifecycle overall revenue as well as infrastructure systems revenue as an objective/constraints in the optimization process. More importantly, the model enables better and smoothed cash flows which consequently allow consistent operations, levelled resources and expenditure. As a result, project organization portfolios become more efficient.

The model is applied to a real estate development that is under construction in Egypt. The original feasibility was based on an approved master plan and implementation schedule. The construction of infrastructure projects and a few number of REPs have started in early 2010. The unrest in Egypt has started in January 2011 where the developer has decided to postpone the execution of those projects that have not started yet due to the market related risks.

The results show that the introduced framework/model would represent an effective optimization tool that is able to support decision-makers in minimizing the impact of unforeseen risks on their investment. Levelling their resources and risk control improves organizing portfolio selection due to the more efficient utilization of organizational resources at any development point in time.

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