TIME, COST AND QUALITY TRADE OFF ANALYSIS IN CONSTRUCTION OF PROJECTS

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Abstract - The foremost objective of construction comes is to complete the project per to an offered budget, within a planned schedule, and achieving a pre-specified extent of quality. Therefore, time, cost, and quality unit thought-about the foremost necessary attributes of construction comes. The aim of this study is to include quality into the standard two-dimensional time-cost trade-off (TCT) therefore on develop a sophisticated three dimensional time-cost-quality trade-off (TCQT) approach. Time, cost, and quality of construction comes unit reticulate and have impacts on one another. It's a troublesome task to strike a balance among these three conflicting objectives of construction comes since no answer is ideal for the three objectives. The overall performance of a project regarding time, cost, and quality is decided by the amount, cost, and quality of its activities. These attributes of every activity place confidence within the execution chance by that the activity's work is completed. It's required to develop an approach that's capable of finding an optimum or about to optimum set of execution selections for the project's activities therefore on attenuate the project's total worth and total amount, whereas its overall quality is maximized. For constant purpose, three varied Microsoft surpass based totally TCQT models unit developed as follows:

→ First, a simplified model is developed with the target of optimizing the entire amount, cost, and quality of straightforward construction comes utilizing the GA-based surpass add in Evolver.

→ Second, a random model is developed with the target of optimizing the overall amount, cost, and quality of construction comes applying the spirited approach therefore on admit uncertainty related to the performance of execution selections and therefore the whole project.

→ Third, a sophisticated multi objective improvement model is developed utilizing a self-developed improvement tool having subsequent capability.

Key Words: **Time, Cost, Quality, Trade-off analysis & Construction**

INTRODUCTION

The development trade is one among the foremost necessary industries within the world and is taken into account one among the foremost economy conducive ones. That's why construction engineering and management analysis is of nice importance to the success of that very important trade. Consistent with construction management references, a project is outlined as "a temporary endeavour undertaken to make a novel product or service." (PMI, 2008). In alternative words, a project could be a sequence of distinctive and connected activities having one goal that has to be completed by a selected time, at intervals a budget and consistent with specifications. Any distinctive project incorporates a planned period, an outlined scope, an calculable budget, and pre-specified specifications. Therefore, time, cost, and specifications are the 3 constraints that are limiting the project success. Specifications of comes embrace however don't seem to be restricted to quality, safety, property, and lots of alternative technical or written agreement details (Hegazy, 2002). For the projected analysis, the fundamental goal of any construction project is to end the project consistent with an offered budget, at intervals a planned schedule, and achieving a needed extent of quality.

OBJECTIVE

The main objective is to check the TCT and TCQT approaches and techniques so as to develop innovative and sensible improvement models that square measure applicable for construction comes. The event of such models supports the efforts of construction companies and general contractors to boost projects' performance in terms of your time, cost, and quality. The elaborate analysis objectives square measure as follows:

- Investigating a sensible approach for quantifying and evaluating the standard performance of execution choices and also the whole project.
- Studying the TCQT as a distinct improvement drawback, that is a lot of relevant to construction comes. For the distinct TCQT, every project's activity has totally different modes or choices of execution and every mode has its corresponding time, value and quality price severally.
- Summarizing recent improvement approaches to propose AN applicable one for TCQT issues. It's needed to propose a sturdy multi-objective improvement approach that's capable of effectively optimizing multiple conflicting objectives of your time, cost, and quality among a thought-about project.

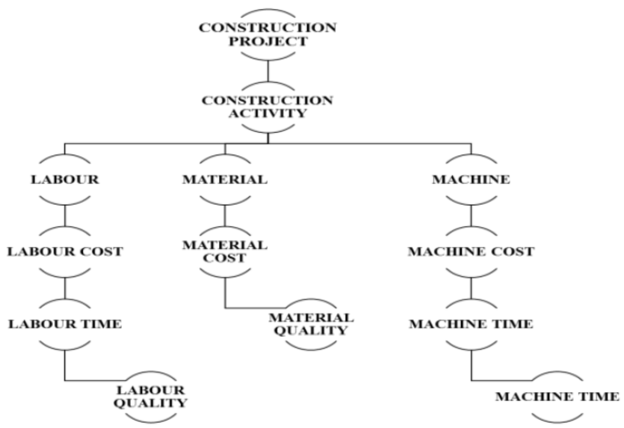
- Incorporating the uncertainty related to the performance of execution choices and also the performance of the total project relating to time, cost, and quality.
- Developing a sturdy, straightforward to use, stand out based mostly TCQT models so as to come up with execution eventualities that deliver the goods the objectives of a thought-about project.

THE METHODOLOGY IS AS FOLLOWS:

- **An in depth literature review:** General overviews of schedule, cost, quality, and optimisation are illustrated. The literature review of the most recent analysis developments is then conducted so as {to investigate to analysis to analyse} and analyse relevant research studies and practices in each two-dimensional time-cost trade-off (TCT) analysis and 3 dimensional time-cost-quality trade-off (TCQT) analysis so as to spot their limitations and downsides.
- **Development of 3 TCQT models:** supported the literature review of potential enhancements, 3 TCQT models is developed. the most purpose of those 3 five models is to get associate degree best or close to best combination of construction choices with the target of at the same time minimizing the whole project length, total cost, while
  Maximizing its total quality. The 3 projected models are developed and enforced in Microsoft stand out to learn from the advanced optimisation add-in tools and stand out options and capabilities.
- **Validation of the developed models:** The developed models are applied to straightforward case studies so as an example their capabilities, validate their results, and demonstrate their potency. Results of the developed models are compared with results of the literature models. 3 case studies are analysed by the developed models as follows: o A case study to demonstrate the power of the simplified model to get satisfactory results compared to those obtained by the literature. o A case study as an example the power of the random model to contemplate uncertainty related to execution choices and to review the random trade-off among time, cost, and quality of the project. A case study to demonstrate the power of the advanced model to with efficiency analyse TCT issues additionally to TCQT issues.
- **Conclusions:** A comprehensive analysis of the developed models and their results is conducted. Limitations and capabilities of the developed models are illustrated and their contributions and significance are mentioned.

WORK BREAK DOWN STRUCTURE

A work breakdown structure (WBS), in project management and systems engineering, may well be a deliverable-oriented breakdown of a project into smaller parts. A chunk breakdown structure may well be a key project deliverable that organizes the team's work into manageable sections. Once academic degree activity is just too huge or advanced for a reliable amount estimate project guide lines state than a non-public activity that takes up over 10 p.c of the project schedule ought to be attenuated. A project manager uses a clear stage down technique to chop back the activity to smaller tasks. Ideally the project manager can estimate the amount of tasks that individual employees perform further accurately than the total activity.



CALCULATION

1) To calculate the whole project cost, the given equation is used.

C = Σ DC + IC * D + Pen* (D-deadline) – Bon* (deadline- D) ,
Wherever C is the total project value, Σ Dc is the summation of direct costs of all activities, and IC * D is indirect cost per time unit multiplied by total duration. Pen* (D-deadline) is the penalty of delay per time unit multiplied by the number of delay units and Bon* (deadline- D) is bonus per time unit multiplied by no of early units.

2) **Early Finish (EF) = Early Start (ES) + Dur**
3) **Late Start (LS) = Late Finish (LF) – Dur**
4) **Total Float (TF) = LS – ES = LF – EF**
5) to evaluate the quality of each execution option, **qi =** $\Sigma \boldsymbol{Wti,k * qi,klkk=1}$
6) to evaluate the overall project quality, **QT =** $\Sigma\ \boldsymbol{Wti\ ni * qi = \Sigma\ Wti\ n\ i=1\ \Sigma\ Wti, * qi, l\ kk=1}$

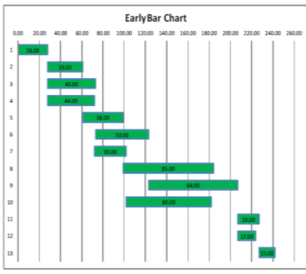
Wherever , is the weight of quality indicator (k) of activity (i) and $qi,\ l$ is the performance or result of quality indicator (k) in activity (i) using resource utilization option (l). Wti is the weight of activity (i) and the term qi or $\Sigma\ Wti, * qi, l\ kk$ =1 is the quality of each activity when executed by a specific execution option (l).

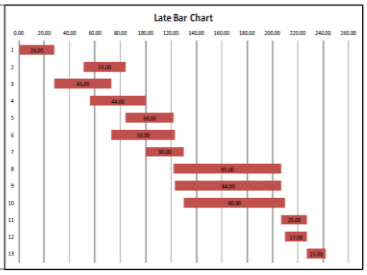
RESUTLS

The Simplified Model Output:

Activity ID	No of Available Options	Selected Optimum Option				CPM Calculations					
		Option Index	Duration (days)	Cost ($)	Activity Quality	ES	EF	LS	LF	TF	Critical Activities
1	5	1	14	2400	98.4	0	14	0	14	0	Activity 1 is Critical
2	5	1	15	3000	96.6	0	15	13	28	13	
3	3	1	15	4500	99.25	0	15	46	61	46	
4	3	3	20	30000	61.15	0	20	46	66	46	
5	4	1	22	20000	99.2	14	36	21	43	7	
6	3	1	14	40000	96.25	14	28	14	28	0	Activity 6 is Critical
7	3	1	9	30000	96	36	45	60	69	24	
8	5	1	14	220	95	28	42	55	69	27	
9	5	1	15	300	99.5	28	43	28	43	0	Activity 9 is Critical
10	3	1	15	450	95.2	28	43	28	43	0	Activity 10 is Critical
11	3	1	12	450	95.7	45	57	69	81	24	
12	4	1	22	2000	98.05	43	65	43	65	0	Activity 12 is Critical
13	3	1	14	4000	97.4	15	29	61	75	46	
14	3	1	9	3000	99.3	43	52	66	75	23	
15	1	1	16	3500	99.4	65	81	65	81	0	Activity 15 is Critical
16	5	1	20	3000	97.1	52	72	75	95	23	
17	3	1	14	4000	97.9	81	95	81	95	0	Activity 17 is Critical
18	3	1	9	3000	97.45	95	104	95	104	0	Activity 18 is Critical

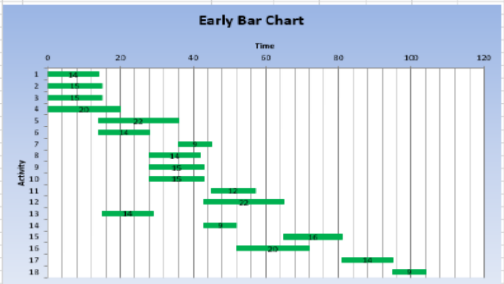
Activity NO	Expected Duration	CPM Calculations					
		ES	EF	LS	LF	TF	Critical Activities
1	28.00	0.00	28.00	0.00	28.00	0.00	Activity 1 is Critical
2	33.00	28.00	61.00	51.00	84.00	23.00	
3	45.00	28.00	73.00	28.00	73.00	0.00	Activity 3 is Critical
4	44.00	28.00	72.00	56.00	100.00	28.00	
5	38.00	61.00	99.00	84.00	122.00	23.00	
6	50.00	73.00	123.00	73.00	123.00	0.00	Activity 6 is Critical
7	30.00	72.00	102.00	100.00	130.00	28.00	
8	85.00	99.00	184.00	122.00	207.00	23.00	
9	84.00	123.00	207.00	123.00	207.00	0.00	Activity 9 is Critical
10	80.00	102.00	182.00	130.00	210.00	28.00	
11	20.00	207.00	227.00	207.00	227.00	0.00	Activity 11 is Critical
12	17.00	207.00	224.00	210.00	227.00	3.00	
13	15.00	227.00	242.00	227.00	242.00	0.00	Activity 13 is Critical





The Schedule Module Output of the Stochastic Model

TCQ Model Output	
Total Penalty ($)	0
Total Bonus ($)	0
Total Direct Cost ($)	153820
Total Indirect Cost ($)	156000
Total Duration of the Project	104
Total Quality performance of the	93.702
Total Cost of the Project ($)	309820



Early Bar Chart

Solution	Resource Utilization Options for Activities																		Time	Direct Cost	Total Cost	Quality
	Act.1	Act.2	Act.3	Act.4	Act.5	Act.6	Act.7	Act.8	Act.9	Act.10	Act.11	Act.12	Act.13	Act.14	Act.15	Act.16	Act.17	Act.18				
Min. Direct Cost	3	5	3	3	4	3	3	5	3	1	2	4	3	3	1	5	1	1	129	103,700	297,200	70.05%
Min. Total Cost	1	5	3	3	4	3	3	5	1	1	3	1	3	3	1	5	1	1	114	105,270	276,270	71.55%
Min. Duration	1	2	2	1	3	1	3	4	1	1	2	1	3	3	1	3	1	1	104	150,358	306,358	84.28%
Max. Quality	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	104	168,820	324,820	97.63%
Min. (T*C/Q)	1	1	1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	104	153,820	309,820	93.70%

Results of the Simplified Model

Solution	Resource Utilization Options for Activities													Duration	Duration with P=90%	Direct cost	Direct cost with P=90%	Total cost	Total cost with P=90%	Quality	Quality with P=90%
	1	2	3	4	5	6	7	8	9	10	11	12	13								
Min. Direct Cost	3	1	2	1	1	1	1	1	2	1	1	2	3	228.167	230.809	2076	2090.354	4357.667	4372.02	0.8793	0.7019106
Min. Total Cost	3	1	2	1	1	2	1	1	2	1	1	2	3	220.167	222.355	2116	2130.354	4317.667	4332.02	0.8353	0.6479072
Min. Duration	3	3	3	2	1	3	3	3	3	2	3	3	3	199	201.491	2481	2497.429	4471	4487.429	0.604	0.3476897
Max. Quality	1	1	1	1	1	1	1	1	3	1	1	1	3	238	241.225	2077	2093.148	4657	4673.148	0.9253	0.7820515
Min. (T*C/Q)	3	1	1	1	1	1	1	1	3	1	1	1	3	229	232.225	2081.00	2097.15	4371.00	4387.148	0.9233	0.767836

Results of the literature example (Zhang and Xing, 2010)

AA BB CC

Activity No	Activity ID	Activity Description	Execution Option	
			Index	Description
1	1	A	1	aaaa
2	2	B	2	bbb
3	3	C	1	aaaa
4	4	D	3	cccc
5	5	E	2	bbb
6	6	F	1	aaaa
7	7	G	1	aaaa
8	8	H	2	bbb
9	9	I	1	aaaa
10	10	J	1	aaaa
11	11	K	1	aaaa
12	12	L	1	aaaa
13	13	M	1	aaaa
14	14	N	1	aaaa
15	15	O	1	aaaa
16	16	P	2	bbb
17	17	Q	1	aaaa
18	18	R	1	aaaa

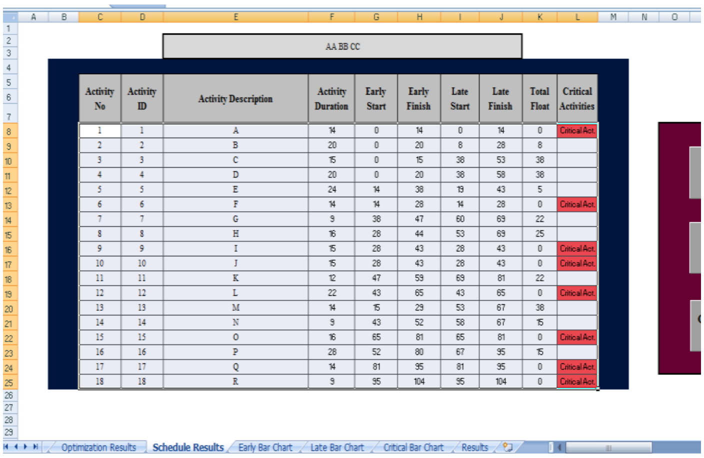
Select Scenario

Total Duration	104
Total Direct Cost	149715
Total Cost	305715
Total Quality	92.239

CPM Calculations

Quality Data / Optimization Process / Optimization Results / Schedule Results / Early Bar Chart / Late Bar Chart

Optimization results for a selected scenario of the advanced TCQ

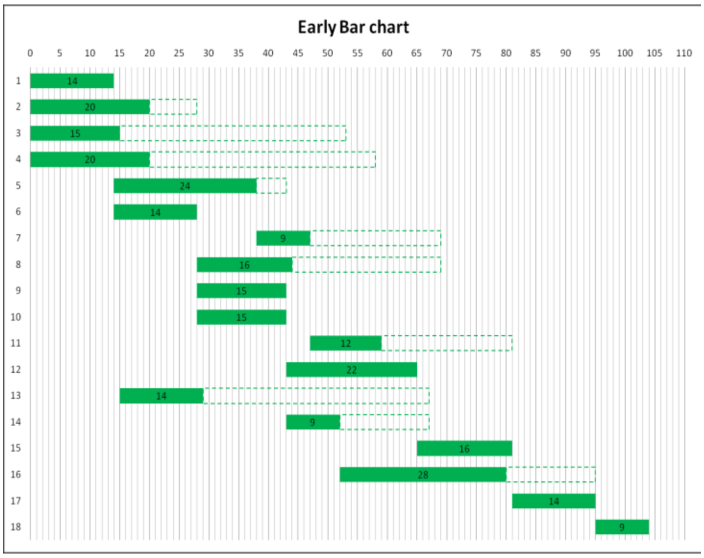


AA BB CC

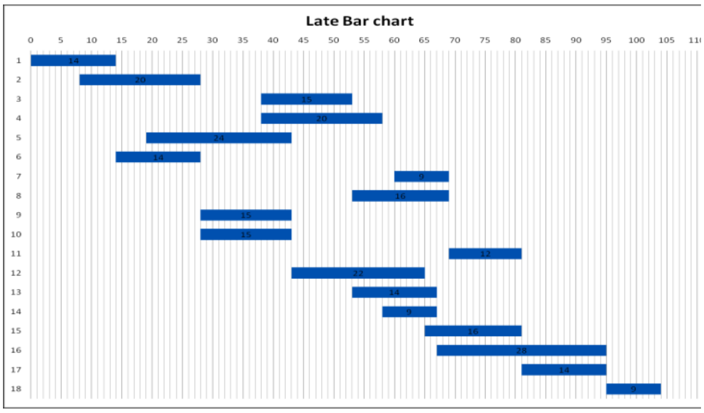
Activity No	Activity ID	Activity Description	Activity Duration	Early Start	Early Finish	Late Start	Late Finish	Total Float	Critical Activities
1	1	A	14	0	14	0	14	0	Critical Act.
2	2	B	20	0	20	8	28	8	
3	3	C	15	0	15	38	53	38	
4	4	D	20	0	20	38	58	38	
5	5	E	24	14	38	19	43	5	
6	6	F	14	14	28	14	28	0	Critical Act.
7	7	G	9	38	47	60	69	22	
8	8	H	16	28	44	53	69	25	
9	9	I	15	28	43	28	43	0	Critical Act.
10	10	J	15	28	43	28	43	0	Critical Act.
11	11	K	12	47	59	69	81	22	
12	12	L	22	43	65	43	65	0	Critical Act.
13	13	M	14	15	29	53	67	38	
14	14	N	9	43	52	58	67	15	
15	15	O	16	65	81	65	81	0	Critical Act.
16	16	P	28	52	80	67	95	15	
17	17	Q	14	81	95	81	95	0	Critical Act.
18	18	R	9	95	104	95	104	0	Critical Act.

Optimization Results | Schedule Results | Early Bar Chart | Late Bar Chart | Critical Bar Chart | Results

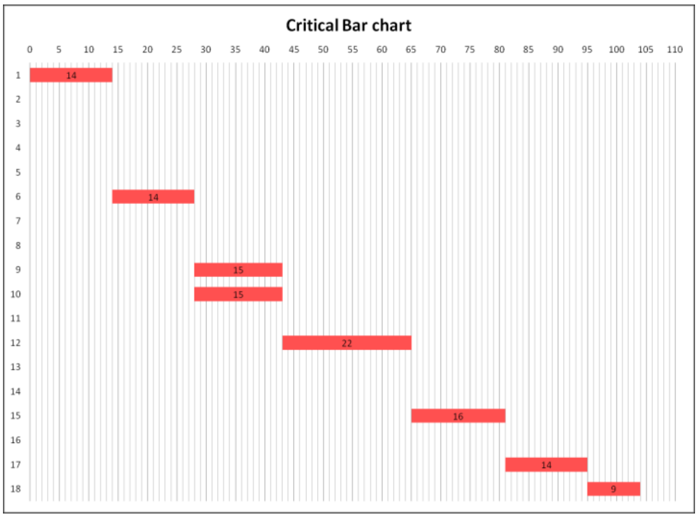
Scheduling Results for a Selected Scenario of the Advanced TCQ Model



Early Bar Chart for a Selected Scenario of the Advanced TCQ Model



Late Bar Chart for a Selected Scenario of the Advanced TCQ Model



Critical Bar Chart for a Selected Scenario of the Advanced TCQ Model

Results and Analysis

The advanced TCQ model results for varied optimisation approaches and varied optimisation objectives.

The following conclusions were reached by the generated results:

1. Compared to results that obtained by literature, (Hegazy & Ayed, 1999), (El-Rayes & Kandil, 2005), and (Zheng et al. , 2004), satisfactory results were obtained by the advanced TCQ model.

2. Compared to results of the simplified TCQ model utilizing the Evolver add-in, comparable results were obtained by the advanced TCQ model utilizing the self-developed optimisation tool.

3. it's obvious that the NSGAII approach outperforms the opposite 2 approaches in analysing each TCT and TCQT issues.

4. It demonstrate the impact of objectives' weights of the doc approach on the obtained solutions. Therefore, it's suggested to use the doc approach once there's a preference for a particular objective.

5. supported conducted tests and in line with the developed code, it's suggested to line the population size between fifty and a hundred and also the range of generations between a hundred and two hundred. it's suggested to line the crossover rate between 0.4and 0.6 and also the initial mutation rate between 0.05 0.3.

6. For the MAWA approach, it's suggested to cut back the initial mutation rate (Pmi) so as not to disrupt the created offspring solutions. Pmi of 0.05 generates satisfactory solutions. 7. programming results provided by the advanced TCQT model were compared with results created by MS Project and each were identical.

The GP Approach Results																							
Solution	Weights of Objectives			Total Duration	Direct Cost	Total Cost	Total Quality	Execution options for activities															
	Wt	Wc	Wq					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1	0	0	104	163,470	319,470	88.95	1	3	3	1	1	1	1	5	1	1	3	1	2	3	1	2
2	0	1	0	108	122,320	284,320	80.11	1	3	1	3	4	2	3	5	1	1	1	1	3	1	1	5
3	0	0	1	107	168,755	329,255	97.46	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	1
4	0.333	0.333	0.333	104	150,320	306320	92.62	1	1	1	3	2	1	1	1	1	1	1	1	1	1	1	2

The GP Approach Results of the Advanced TCQ Model

The MAWA Approach Results																				
Solution	Total Duration	Direct Cost	Total Cost	Total Quality	Execution options for activities															
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	104	161,015	317,015	91.63	1	2	2	1	1	1	2	2	1	1	2	1	1	2	1	1
2	107	151340	311840	89.71	1	4	1	3	1	1	1	3	2	1	2	1	1	3	1	1
3	104	145,115	301,115	86.81	1	4	2	3	1	1	2	2	1	1	2	1	1	2	1	1
4	106	155,070	314070	87.54	1	2	2	1	1	1	3	5	1	1	1	2	3	2	1	4

The MAWA approach results of the advanced TCQ model

The NSGAII Approach Results																					
Solution	Total Duration	Direct Cost	Total Cost	Total Quality	Execution options for activities																
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	108	122,400	284,400	80.25	1	3	1	3	4	2	3	3	1	1	1	1	3	1	1	5	1
2	104	162820	318820	95.16	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1
3	104	150,320	306,320	92.62	1	1	1	3	2	1	1	1	1	1	1	1	1	1	1	2	1
4	104	141,100	297100	88.67	1	3	1	3	2	1	3	3	1	1	1	1	1	1	1	2	1
5	104	149,820	305820	92.2	1	1	1	3	2	1	1	1	1	1	1	1	1	1	1	4	1
6	104	168,820	324820	97.63	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

The NSGAII approach results of the advanced TCQ model

The GP Approach Results for TCT																					
Solution	Weights of Objectives		Total Duration	Direct Cost	Total Cost	Execution options for activities															
	Wt	Wc				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1	0	104	152,858	308,858	1	5	2	2	1	1	1	4	1	1	1	1	3	1	1	3	1
2	0	1	108	119,270	281,270	1	5	3	3	4	2	3	5	1	1	3	1	3	3	1	5	1
3	0.5	0.5	105	127,270	284,770	1	5	3	3	4	1	3	5	1	1	3	1	3	3	1	5	1

The GP approach results of the advanced TCQ model for TCT

The MAWA Approach Results for TCT																					
Solution	Total Duration	Direct Cost	Total Cost	Execution options for activities																	
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	104	140,700	296,700	1	4	1	3	3	1	2	3	1	1	1	1	1	2	1	1	1	1
2	107	130,920	291,420	3	1	3	3	4	1	2	5	1	1	1	1	3	3	1	5	1	1
3	106	136,170	295,170	3	4	1	3	3	1	2	1	1	1	3	1	3	3	1	4	1	1

The MAWA approach results of the advanced TCQ model for TCT

The NSGAII Approach Results for TCT																				
Solution	Total Duration	Direct Cost	Total Cost	Execution options for activities																
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	104	132,270	288,270	1	5	3	3	3	1	3	5	1	1	3	1	3	3	1	5	1
2	108	119,270	281,270	1	5	3	3	4	2	3	5	1	1	3	1	3	3	1	5	1
3	105	127,270	284,770	1	5	3	3	4	1	3	5	1	1	3	1	3	3	1	5	1

The NSGAII approach results of the advanced TCQ model for TCT

CONCLUSIONS

The principal plan of TCQT is to strike a balance among the conflicting objectives of time, cost and quality. There are two categories of trade-off problems: (1) continuous trade off problems, in which the relation among time, cost, and quality has been considered a continuous function; (2) separate trade-off issues, during which the relation among time, cost, and quality has been through of separate or isolated. Separate time-cost-quality relationships are preferred for 2 main reasons: (1) it's a lot of relevant to globally construction projects; (2) it's appropriate for modelling any general time-cost relationship. For minimizing techniques, evolutionary algorithms are preferable and unremarkably used as a result of they can deal with more than one objective, easily achieve diverse solutions, and they are more effective when applied to large-scale issues. Amongst varied EA techniques, GA has been extensively utilised for minimizing issues generally and construction management issues specially. Multi-objective optimization approaches have been also reviewed. 3 approaches of MOO techniques are mentioned, that are measure goal programming (GP), Pareto optimum, and non-dominated sorting genetic algorithmic program (NSGA-II). The NSGA-II has demonstrated to be one of the most robust algorithms for MOO problems. Three TCQT models were developed in MS Excel: the simplified model to optimize the objectives of time, cost, and quality of simple projects; the stochastic model to analyse projects considering uncertainty; and the advanced model to analyse both TCT and TCQT for large-scale projects. The principal objective of such models is to find an optimal or near optimal set of execution options for a project's activities in order to minimize the project's total price, minimize its total duration, and maximize its overall quality. The Evolver add-in software was utilized as an optimization tool for the first two models; but, a self-developed minimizing tool utilizing three various optimization approaches was utilised for the advanced model. To validate the developed models and demonstrate their efficiency, they were applied to case studies introduced by literature. Compared to results obtained by literature, satisfactory results were obtained by the developed models. Additionally, the advanced TCQ model utilizing the self-developed minimizing tool generated comparable results compared to those obtained by the Evolver add-in.

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