Resource-constrained Time-cost-quality-energy-environment Tradeoff in Project Scheduling by Considering Blockchain Technology: A Case Study of Healthcare Project

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Resource-constrained time-cost-quality-energy-environment tradeoff in project scheduling by considering blockchain technology: A case study of healthcare project

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Abstract

Blockchain Technology (BCT) is expanding day by day and is used in all pillars of life and projects. In this research, we survey applicable of BCT in project management for the first time. We presented a Resource-Constrained Time-Cost-Quality-Energy-Environment tradeoff problem in project scheduling by considering BCT (RCTCQEEBCT). We utilize hybrid robust stochastic programming, worst case and Conditional Value at Risk (CVaR) to cope with uncertainty and risks. This type of robustification and risk-averse is presented in this research. A real case study is presented in a healthcare project. We utilize GAMS-CPLEX to solve the model. Finally, we analyze finish time, conservative coefficient, the confidence level of CVaR and the number of scenarios. The most important research result is that applying BCT decreases cost, energy, and pollution and increases quality. Moreover, the total gap between RCTCQEEBCT and without BCT is approximately 2.6%. When compacting finish time happens or if the conservative coefficient increases to 100%, costs, energy, and pollution environment increase, but quality decreases. If the confidence level of CVaR increase, the cost, energy and environment function functions grow up and quality is approximately not changed.

Keywords: Time-cost-quality-energy-environment, tradeoff, blockchain, healthcare, project scheduling.

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1. Introduction

Nowadays, Blockchain Technology (BCT) is one of the novel technology can change the world and move to decentralize and remove inefficiencies of centralized systems. Recently, Using BCT in Project Management Offices (PMOs) is suggested by researchers (Hewavitharana, Nanayakkara, & Perera, 2019). Applying this technology makes to improve and to do activities well and on time. For example, defining suppliers' delay when they act actions with disruption by embedding BCT is concise. Moreover, the smart contract can help pay the vendor and subcontractor automatically and remove the delay in payment (Akhavan, Ravanshadnia, & Shahrayini). This issue decreases cost, improves the quality of activity, energy consumption, and reduces executing time and project pollution (Kim, Lee, & Kim, 2020).

Of course, there is not much research on the applicability of BCT in project management. We need to show how to improve scheduling, quality, energy, and pollution by considering BCT in the mathematical model. However, increasing resiliency, agility and sustainability are advantages of BCT in the project management area (Ivanov, 2020). Resiliency and flexibility in facing costs by doing activities short and increasing transparency in transactions and exchange with vendors and suppliers with agility (Kamble et al., 2021). Using BCT makes to smooth and decreases the sharpness of costs, quality, energy, and environment in a compact situation (cf. Figure 1).

Figure 1. Effects of Blockchain technology on project management

Time-cost-quality-energy-environment tradeoff (TCQEE) is one of the subjects that shows how BCT helps schedule well and improve sustainability and resource constraints. In the future, we have to go to novel technology to amplify resiliency in a complex situation like COVID-19 and natural disasters and disruptions in project management. The leading organization in the project industry worldwide tries to minimize the time of projects and do more tasks.

Eventually, the innovation of this research and the main objective is as follows:

1. Applying BCT in project scheduling in TCQEE problem,
2. Considering risk and robustness in TCQEE model,
3. Sustainability, resiliency, and agility improvement in project scheduling by RCTCQEEBCT model.

The paper is organized as follows. In Section 2, we survey related work on time-cost tradeoff. In Section 3, the novel TCQEE by considering BCT is stated. In Section 4, the results of research and sensitivity analysis are presented. In Section 5, the managerial insights and practical implications is discussed. In Section 6, the conclusion is summarized.

2. Survey on related work

One of the problems that show a good relation of pillars of project management in the present is the time-cost tradeoff problem. However, many researchers have contributed to this problem in the recent decade.

2.1. Time-cost tradeoff

Toğan and Eirgash (2018) studied a TC trade-off. A contribution of this research was using non-dominating sorting multi-objective teaching learning-based optimization (NS-MTLBO) algorithm with a new initial population approach. Toğan and Eirgash (2019) surveyed a TC tradeoff optimization for construction projects. They suggested teaching learning-based optimization (TLBO) with Modified Adaptive Weight Approach (MAWA) for solving the model. They found that MAWA-TLBO has better performance than other algorithms. Ballesteros-Pérez, Elamrousy, and González-Cruz (2019) developed a non-linear TC tradeoff with activity crashing and collaborative or non-collaborative resources. They utilized a Genetic Algorithm (GA) to solve the model.

2.2. Time-cost-quality tradeoff

Wood (2017) surveyed a time-cost-quality (TCQ) tradeoff for Gas and oil project. They applied stochastic and fuzzy multi-objective for optimization. They solve the model by using a memetic multi-objective algorithm. Kosztyán and Szalkai (2018) expressed a hybrid TCQ tradeoff problem. They suggested a matrix-based method with task dependencies and undecided, supplementary task completion. Wang, Abdallah, Clevenger, and Monghasemi (2019) considered a TCQ tradeoff for planning construction projects. They used multi-objective optimization of Non-Dominated Sorting Genetic Algorithms (NSGA-II). Mrad, Al-Gahtani, Hulchafo, Souayah, and Bamatraf (2019) suggested a Mixed Integer Linear Programming (MILP) for TCQ tradeoff. They considered project budget as a constraint. They utilized Monte-Carlo Simulation for getting results.

Banihashemi, Khalilzadeh, Shahraki, Malkhalifeh, and Ahmadizadeh (2021) presented a TCQ tradeoff with environmental impacts for construction projects. They utilized GAMS software to gain results and obtain different scenarios for ecological impacts. Luong, Tran, and Nguyen (2021) optimized a multi-mode TCQ tradeoff for a construction project. They utilized opposition multiple objective difference evolution (OMODE) for optimizing the model. Moreover, they compared OMODE with NSGA-II, Multiple Objective Particle Swarm Optimization (MOPSO), Multiple Objective Differential Evolution (MODE). They found that the proposed algorithm has better performance than other algorithms. Sharma and Trivedi (2022) modeled a TCQ tradeoff for construction projects. They applied the Analytical Hierarchy Process (AHP) to gain weight between activity and quality. Finally, they used NSGA-II to obtain Pareto front for time, cost, quality.

2.3. Time-cost-quality/risk trade-off

Tran and Long (2018) presented a time-cost-risk (TCR) tradeoff. They applied adaptive multiple objective differential evolution (AMODE) for solving the model. They suggested considering risks in their model to enhance schedule flexibility. Long, Tran, and Nguyen (2019) optimized the multi-mode TCR tradeoff problem. To solve the model, They considered Hybrid multiple objective evolutionary algorithms for optimizing by Artificial Bee Colony (ABC) and differential evolution (DE). They found that MOABCDE has more efficiency to show Pareto front of the model.

Nwaneri and Anyaeche (2018) proposed a Time-Cost-Quality-Risk (TCQR) Tradeoff Model in Magnetic Resonance Imaging Installation Project. Moreover, They added a fuzzy number to tackle

with uncertainty. They solved the model by Multi-objective Genetic Algorithm (MOGA) and applied Technique for the Order of Preferences by Similarity to Ideal Solution (TOPSIS). The results indicate a tradeoff relationship exists among time, cost, quality and risks. Mahdiraji et al. (2021) considered a TCQR tradeoff model with a knowledge-based approach.

Moreover, They added hesitant fuzzy information to tackle uncertainty. An R&D project application was the real case study. They found that they reduced the project's time by 20% compared with the deterministic approach.

2.4. Time-cost-quality-energy-environment tradeoff

Lotfi et al. (2020) suggested a complete form of tradeoff. They surveyed a time-cost-quality-energy-environment tradeoff with resource-constrained (RCTCQEE). The real case study was bridge construction. They applied robust convex optimization to cope with uncertainty. They embedded Augmented Epsilon Constraint (AUGEPS) to get results for multi-objective.

Table 1. Survey of related work.

Reference	Model type	Platform	Tradeoff						Uncertainty	Solution approach	Case Study
			Time	Cost	Quality	Energy	Environment	Risk			
(Wood, 2017)	TCQ	-	✓	✓	✓	-	-	-	Stochastic, fuzzy	*MILP	Gas and oil
(Tran & Long, 2018)	TCR	-	✓	✓	-	-	-	✓	-	MILP + AMODE	Numerical Example (NE)
(Toğan & Eirgash, 2018)	TC	-	✓	✓	-	-	-	-	-	MILP+ NS-MTLBO	NE
(Nwaneri & Anyaeche, 2018)	TCQR	-	✓	✓	✓	-	-	✓	Fuzzy	MILP+ MOGA	MRI machine installation
(Kosztyán & Szalkai, 2018)	TCQ	-	✓	✓	✓	-	-	-	-	MILP+ matrix-based	NE
(Wang et al., 2019)	TCQ	-	✓	✓	✓	-	-	-	-	MILP + NSGA-II	Construction
(Toğan & Eirgash, 2019)	TC	-	✓	✓	-	-	-	-	-	MILP + MAWA-TLBO	Construction

(Mrad et al., 2019)	TCQ	-	✓	✓	✓	-	-	-	Stochastic	MILP+MOGA	NE
(Ballesteros-Pérez et al., 2019)	TC	-	✓	✓	-	-	-	-	Probably	MILP+GA	Construction
(Long et al., 2019)	TCR	-	✓	✓	-	-	-	✓		MILP+ABC+DE	construction
(Lotfi et al., 2020)	RCTCQEE	-	✓	✓	✓	✓	✓	-	Robust convex	MILP + AUGEPS	Bridge
(Banihashemi et al., 2021)	TCQE	-	✓	✓	✓	-	✓	-	-	MILP	Construction
(Mahdiraji et al., 2021)	TCQR	-	✓	✓	✓	-	-	✓	Fuzzy	MILP	Construction
(Luong et al., 2021)	TCQ	-	✓	✓	✓	-	-	-	-	MILP - OMODE	Construction
(Sharma & Trivedi, 2022)	TCQ	-	✓	✓	✓	-	-	-	-	MILP+NSGA-II	Construction
This research	RCTCQEEBCT	Blockchain	✓	✓	✓	✓	✓	✓	Robust Stochastic+ Risk	MILP	Health care

The classification of the literature is addressed in Table 1. It can be seen; researchers do not survey the RCTCQEEBCT problem. This study investigates the RCTCQEEBCT problem and used mathematical problems to optimize the best time, cost, energy, environment for projects by considering BCT.

The main innovation of this research is as follows:

1. Applying BCT in TCQEE model,
2. Considering risk and robustness in TCQEE model,
3. Improving sustainability, resiliency and agility in project scheduling.

3. Problem description

In this research, we want to show the effect of BCT in project scheduling until sustainability, resiliency, and agility of projects improve. Therefore, we develop a new model of the TCQEE model by considering BCT. When we add BCT in this model, all parameters cost, quality, energy, environment improve, but we have fix cost and variable (maintenance) cost for establishing BCT. Finally, we want to show how the model selects to run with BCT or without BCT by considering

the fixed cost and maintenance cost of BCT. Moreover, we have resource constraints and want to cope with the risk of activity disruption and improve projects' resiliency, robustness, and sustainability. We add risk criteria and robust stochastic optimization to tackle with robustness. Using BCT makes to smooth and decreases the sharpness of costs, quality, energy and environment in a compact situation.

To describe the mathematical model, consider a project based on an Activity on Node (AON) network. This network has $i \in \{1, \dots, |I|\} \subset I$ nodes that show the activities. The activity i has a normal time (t_{is}), normal cost, quality, energy, and environment (pollution) (θ_{kis}) under scenario s , while the compacted time (t'_{is}) and compact cost, quality, energy, and environment (pollution) (θ'_{kis}) under scenario s are denoted.

Figure 2. Effect of BCT on compact of cost, quality, energy, environment.

3.1. Assumptions

The main assumptions of the proposed model are as follows:

1. No activity is done before providing the prerequisites (Nunez, Kuo, & Chiang, 2016).
2. Time, cost, quality, energy, and environment (pollution) are uncertain for every activity.

3. It should be noted that $t_{is} \geq t'_{is} \mid \theta_{kis} \leq \theta'_{kis} \mid k \in \{\text{Cost, Energy}\}$, and

$\theta_{kis} \geq \theta'_{kis} \mid k \in \{\text{Quality, Environment}\}$.

4. After considering BCT, because of effects of BCT on cost, quality, energy, and environment, θ'_{kis} change to $\theta_{kis} \leq \theta'_{kis}$.

5. Cost and energy consumption increase as time diminishes, and quality and pollution decrease as time reduce.

6. It should be noted that the energy consumption of each activity is estimated based on the consumption amount of energy-based resources.

7. Activities have a daily demand for their required resources.

8. Multiple resources are defined. The supply capacity of resources is restricted and is known at the beginning of the project (Bowman, 1994).

In the following, the mathematical model of the time-cost-quality-energy-environment tradeoff is introduced. In Figure 2, we show that duration (x_{is}) is between normal time (t_{is}) and compact time (t'_{is}).

3.2. Notation list

Indices:

i Set of activity $i, j \in I = \{1, \dots, n\}$,

I_1 Set of activities with a start to start the relationship $I_1 \subset I$,

I_2 Set of activities with a start to finish the relationship $I_2 \subset I$,

I_3 Set of activities with a finish to start the relationship $I_3 \subset I$,

I_4 Set of activities with a finish to finish the relationship $I_4 \subset I$,

j Set of resources $j \in J = \{1, \dots, J\}$,

s Set of scenario $s \in S = \{1, \dots, S\}$,

k Set of objective $k \in K = \{1:\text{Cost}, 2:\text{Quality}, 3:\text{Energy}, 4:\text{Environment}\}$,

Parameters:

t_{is} Normal time of activity i under scenario s ,

t'_{is}	Compact time of activity i under scenario s ,
θ_{kis}	Normal factor for objective k for activity i under scenario s ,
θ'_{kis}	Compact factor for objective k for activity i under scenario s , $\theta_{kis} \leq \theta'_{kis} \mid k \in \{\text{Cost, Energy}\}, \theta_{kis} \geq \theta'_{kis} \mid k \in \{\text{Quality, Environment}\}.$
β	Coefficient of conservative,
αb_k	Impact BCT on objective k ,
φ_{ks}	Indirect factor on objective k under scenario s ,
T	Maximum time of project,
λ_j	Maximum needs of resources j ,
pr_s	Probably of scenario s ,
r_{ijs}	Amount of resource j for activity i under scenario s ,
M	Huge number,
α	The confidence level of CVaR.
fbt_k	Fix coefficient by establishing BCT on objective function k ,

165 *Decision variables:*

166 *Binary variables:*

xbt Activation blockchain technology is equal 1, otherwise 0;

167 *Continues variables:*

st_{is} Start time of activity i under scenario s ,

f_{is} Finish time of activity i under scenario s ,

x_{is} Duration time of activity i under scenario s ,

168 *Auxiliary variables:*

z_k Objective function k ,

θb_{kis} Compact factor of activity i under scenario s by considering BCT,
 $\theta b_{kis} = \theta'_{kis} (1 - \alpha b_k xbt), \theta b_{kis} \leq \theta'_{kis}.$

Γ_{kis}	Direct events for objective function k and activity i under scenario s ,
$\Gamma\Gamma_{ks}$	Summation of direct for objective function k under scenario s ,
Γt_{ks}	Summation of direct and indirect for objective function k under scenario s by considering establishing BCT,
kk_k	Summation of fix cost for establishing BCT,
Δ_k	Auxiliary variable for linearization of max function,
$CVaR_{(1-\alpha)}$	Conditional Value at Risk (CVaR) with a confidence level α ,
v_{ks}	Auxiliary variable for linearization of max function in CVaR,
VaR_k	Value at Risk (VaR) for CVaR,
ww_{is}	Auxiliary variable for linearization of producing binary and positive variable.

169 3.3. RCTCQEEBCT mathematical model

Sustainable objectives:

$$\text{minimize } z_k = (1 - \beta) \sum_s pr_s \Gamma t_{ks} + \beta \left(\frac{\max(\Gamma t_{ks}) + CVaR_{(1-\alpha)}(\Gamma t_{ks})}{2} \right), \quad \forall k \quad (1)$$

subject to:

Resilience constraints (BCT technology):

$$\Gamma t_{ks} = \Gamma\Gamma_{ks} + \varphi_{ks} f_{ns} + kk_k, \quad \forall s, k \quad (2)$$

$$\Gamma\Gamma_{ks} = \sum_i \Gamma_{kis}, \quad \forall s, k \quad (3)$$

$$\Gamma_{kis} = \theta b_{kis} + \frac{\theta_{kis} - \theta b_{kis}}{t_{is} - t'_{is}} (x_{is} - t'_{is}), \quad \forall i, s, k \quad (4)$$

$$\theta b_{kis} = \theta'_{kis} (1 - \alpha b_k xbt), \quad \forall i, s, k \quad (5)$$

$$kk_k = fbt_k \cdot xbt, \quad \forall k \quad (6)$$

Agile, predecessor, successor, and resource constraints:

$$st_{1s} = 0, \quad \forall s \quad (7)$$

$$f_{ns} \leq T, \quad \forall s \quad (8)$$

$$\frac{\sum_i r_{ijs} x_{is}}{f_{js}} \leq \lambda_j, \quad \forall j, s \quad (9)$$

$$t'_{is} \leq x_{is} \leq t_{is}, \quad \forall i, s \quad (10)$$

$$st_{is} + x_{is} \leq f_{is}, \quad \forall i, s \quad (11)$$

$$st_{is} + ss_{is} \leq st_{js}, \quad \forall i, j \in I_1 \quad (12)$$

$$s_{is} + sf_{is} \leq f_{js}, \quad \forall i, j \in I_2 \quad (13)$$

$$f_{is} + fs_{is} \leq st_{js}, \quad \forall i, j \in I_3 \quad (14)$$

$$f_{is} + ff_{is} \leq f_{js}, \quad \forall i, j \in I_4 \quad (15)$$

Decision variables:

$$x_{bt} \in \{0, 1\}, \quad (16)$$

$$st_{is}, x_{is}, f_{is} \geq 0. \quad \forall i, s \quad (17)$$

170 The objective function (1) considered minimizing the weighted expected value, minimax and
 171 Conditional Value at Risk (CVaR) for objective function k include cost, quality, energy,
 172 environment (pollution). This form of the objective function is proposed for robustness and risk-
 173 averse against disruption with the worst condition.

174 Constraints (2) are the summation of direct and indirect for objective function k under scenario s
 175 by considering establishing BCT. Constraints (3) are the summation of direct for objective function
 176 k under scenario s . Constraints (4) are direct events for objective function k and activity i under
 177 scenario s . Constraints (5) are a compact factor of activity i under scenario s by considering BCT.
 178 Constraints (6) are the summation of fixed costs for establishing BCT. Constraints (7) guarantee
 179 that start time equals zero for each scenario. Constraints (8) consider that finish time is less than
 180 the maximum defining time for each scenario. Constraints (9) indicate resource constraints for
 181 proposed model. Constraints (10) express the duration of activity i between compact and normal
 182 time for each scenario. Constraints (11)-(15) are predecessor and successor constraints for
 183 activities. Constraints (16), (17) are decision variables. Constraint (16) is a binary variable for
 184 running BCT in the project network. Constraints (17) are positive variables for start, duration and
 185 finish time of activities.

3.4. Preliminaries for Linearization

The objective functions (1) are non-linear and make the model mixed-integer non-linear programming (MINLP). We transform them to mixed-integer programming (MIP) by mathematical method to improve time solution and solve smoothly (Gondal & Sahir, 2013; Sherali & Adams, 2013).

Linearizing max function:

Suppose: If $\beta = \max(\Omega_s)$, then we can change $\beta \geq \Omega_s, \forall s$.

Linearizing product binary with non-negative variable:

We can change and linearize a binary and a non-negative variable that is produced:

Suppose $z = Ax$, if A be a non-negative and positive variable and x be binary variable. Therefore we can replace these constraints to the model (Glover, 1975):

$$z \geq 0, \quad (18)$$

$$z \leq Mx, \quad (19)$$

$$z \leq A, \quad (20)$$

$$z \geq A - (1 - x)M. \quad (21)$$

It means that if x be zero, z is zero based on equation (18), (19). If x is 1, z is A based on equations (20), (21).

Linearizing CVaR function:

We used Conditional Value at Risk (CVaR), which is a coherent risk measure. Uryasev and Rockfeller designed the CVaR criterion for a novel embed risk measure (Lotfi, Kargar, Gharehbaghi, & Weber, 2021). CVaR (also known as the expected shortfall) is considered as a measure for assessing the risk. CVaR is embedded in portfolio optimization to better risk management (Kara, Özmen, & Weber, 2019; Lotfi, Mehrjerdi, Pishvaei, Sadeghieh, & Weber, 2021). This measure is the average of losses are beyond the VaR point in confidence level. CVaR has a higher consistency, coherence, and conservation than other risk-related criteria.

$$\min CVaR_{(1-\alpha)}(\Gamma\Gamma_s) = VaR + \frac{1}{1-\alpha} \sum_s pr_s v_s, \quad (22)$$

$$v_s \geq \Gamma \Gamma_s - VaR, \quad \forall s \quad (23)$$

$$v_s \geq 0, \quad (24)$$

3.5. Linearization of RCTCQEEBCT

We used linearization by the operational research method. Solving the model by MIP is more straightforward than MINLP in the solver in equations (26) to (36), and these methods decrease time solution and the complexity of the model.

We can write it as follows:

Linearization of RCTCQEEBCT-Step1

$$\text{minimize } z_k = (1 - \beta) \sum_s pr_s \Gamma t_{ks} + 0.5 \beta (\Delta_k + \text{CVaR}_{(1-\alpha)}(\Gamma t_{ks})), \quad \forall k \quad (25)$$

Subject to:

$$\Delta_k \geq \Gamma t_{ks}, \quad \forall s, k \quad (26)$$

$$\text{CVaR}_{(1-\alpha)}(\Gamma t_{ks}) = VaR_k + \frac{1}{1-\alpha} \sum_s pr_s v_{ks}, \quad \forall k \quad (27)$$

$$v_{ks} \geq \Gamma t_{ks} - VaR_k, \quad \forall s, k \quad (28)$$

$$v_{ks} \geq 0, \quad \forall s, k \quad (29)$$

$$\Gamma_{kis} = \theta'_{kis} (1 - \alpha b_k xbt) + \frac{\theta_{kis} - \theta'_{kis} (1 - \alpha b_k xbt)}{t_{is} - t'_{is}} (x_{is} - t'_{is}), \quad \forall i, s, k \quad (30)$$

Constraints (2)-(3), (6)-(17).

Linearization of RCTCQEEBCT-Step2

$$\text{minimize } z_k = (1 - \beta) \sum_s pr_s \Gamma t_{ks} + 0.5 \beta (\Delta_k + \text{CVaR}_{(1-\alpha)}(\Gamma t_{ks})), \quad \forall k$$

$$\Gamma_{kis} = \theta'_{kis} (1 - \alpha b_k xbt) + \frac{\theta_{kis} - \theta'_{kis}}{t_{is} - t'_{is}} (x_{is} - t'_{is}) + \frac{\theta'_{kis} \alpha b_k xbt}{t_{is} - t'_{is}} (x_{is} - t'_{is}), \quad \forall i, s, k \quad (31)$$

Constraints (2)-(3), (6)-(17), (26)-(29).

Linearization of RCTCQEEBCT-Step3

$$\text{minimize } z_k = (1 - \beta) \sum_s pr_s \Gamma t_{ks} + 0.5 \beta (\Delta_k + \text{CVaR}_{(1-\alpha)}(\Gamma t_{ks})), \quad \forall k$$

subject to:

$$\Gamma_{kis} = \theta'_{kis} (1 - \alpha b_k xbt) + \frac{\theta_{kis} - \theta'_{kis}}{t_{is} - t'_{is}} (x_{is} - t'_{is}) + \frac{\theta'_{kis} \alpha b_k ww_{is}}{t_{is} - t'_{is}}, \quad \forall i, s, k \quad (32)$$

$$ww_{is} \geq 0, \quad \forall i, s \quad (33)$$

$$ww_{is} \leq M \cdot xbt, \quad \forall i, s \quad (34)$$

$$ww_{is} \leq x_{is} - tp_{is}, \quad \forall i, s \quad (35)$$

$$ww_{is} \geq x_{is} - tp_{is} - (1 - xbt)M, \quad \forall i, s \quad (36)$$

Constraints (2)-(3), (6)-(18), (26)-(29).

215 The complexity of linearization of RCTCQEEBCT includes numbers of binary, positive, free
 216 variables and constraints are indicated in equations (37) to (40). As can be seen, one of the essential
 217 factors for constraints, positive and free variables, is scenario sets. Relation between scenario and
 218 constraints, positive and free variables is entirely linear.

$$\text{Binary variables} = 1, \quad (37)$$

$$\text{Positive variables} = 4|I||S| + |K||S| + 1, \quad (38)$$

$$\text{Free variables} = 5|K| + 1 + 2|K||I||S| + 2|K||S|, \quad (39)$$

$$\text{Constraints} = 1 + 3|K| + 4|K||S| + 6|I||S| + 2|K||I||S| + |J||S| + 3|S| + |I||I|. \quad (40)$$

219 We suggested scenario reduction and new algorithms to remove constraints and binary variables.
 220 This subject can help solve minimum time.

221 4. Results and discussion

222 This section surveys a healthcare project that establishes a hospital with 500 beds (c.f. Figure 3).
 223 Data and information received from managers of healthcare projects. In this complex situation of
 224 COVID-19, we should run these hospitals as soon as possible in Iran. Patients need beds for
 225 remedy. Therefore, we should establish a hospital with minimum cost, energy, and environment,
 226 and maximum quality to provide patients with good quality.

Figure 3. Healthcare project (hospital 500 bed).

Figure 4. Network activity of hospital with 500 bed.

We show network and predecessor and successor of activities in Figure 4. The number of indices, constraints, variables and parameters is defined for the case study in Table 2, Table 3.

Table 3. Parameters of case study.

Parameters	Value	Unit
t_{is}	$t_{1s}=3 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $t_{2s}=10 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $t_{3s}=18 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $t_{4s}=5 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $t_{5s}=4 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $t_{6s}=4 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$;	Month
t'_{is}	[($t_{is} * 0.9$)]	Month
	$\theta_{11s}=0.1 \cdot 7500000 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $\theta_{12s}=0.2 \cdot 7500000 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $\theta_{13s}=0.3 \cdot 7500000 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $\theta_{14s}=0.15 \cdot 7500000 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $\theta_{15s}=0.15 \cdot 7500000 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $\theta_{16s}=0.1 \cdot 7500000 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$	Dollar
	$\theta_{2is}=[(U(0.8,0.98).10)/10]$	%
θ_{kis}	$\theta_{31s}=0.01 \cdot U(25,30) \cdot 60000 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $\theta_{32s}=0.01 \cdot U(25,30) \cdot 60000 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $\theta_{33s}=0.65 \cdot U(25,30) \cdot 60000 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $\theta_{34s}=0.2 \cdot U(25,30) \cdot 60000 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $\theta_{35s}=0.08 \cdot U(25,30) \cdot 60000 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $\theta_{36s}=0.05 \cdot U(25,30) \cdot 60000 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $\theta_{41s}=0.05 \cdot U(115,120) \cdot 60000 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $\theta_{42s}=0.05 \cdot U(115,120) \cdot 60000 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $\theta_{43s}=0.5 \cdot U(115,120) \cdot 60000 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $\theta_{44s}=0.20 \cdot U(115,120) \cdot 60000 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $\theta_{45s}=0.15 \cdot U(115,120) \cdot 60000 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$; $\theta_{46s}=0.05 \cdot U(115,120) \cdot 60000 \cdot ((s-1)/(S -1) \cdot 0.1+0.95)$;	KWh Ton
θ'_{kis}	$\theta'_{1is}=[(\theta_{1is} \cdot 1.2)]$	Dollar

	$\theta'_{2is} = \theta_{2is} \cdot 0.9;$	%
	$\theta'_{3is} = [\theta_{3is} \cdot 1.2];$	KWh
	$\theta'_{4is} = \theta_{4is} \cdot 0.95;$	Ton
β	50	%
	$\alpha b_1 = 0.1$	-
αb_k	$\alpha b_2 = -0.1$	-
	$\alpha b_3 = 0.1$	-
	$\alpha b_4 = 0.1$	-
	$\varphi_{1s} = 500000/T$	Dollar/ Mon
φ_{ks}	$\varphi_{2s} = 0.02/T$	%/Mon
	$\varphi_{3s} = -100000/T$	KWh/ Mon
	$\varphi_{4s} = 1000000/T$	Ton/M on Month
T	34	
λ_j	0.5	-
pr_s	$1/ S $	%
α	5	%
r_{ijs}	0.5	-
M	10^{100}	-
	$fbt_1 = 40000$	Dollar
fbt_k	$fbt_2 = -0.03$	%
	$fbt_3 = -10000$	KWh
	$fbt_4 = -60000$	Ton

We applied a computer with this configuration: CPU 3.2 GHz, Processor Core i3-3210, 6.00 GB RAM, 64-bit operating system. Finally, we solve the mathematical models by GAMS-CPLEX solver.

The results show that applying BCT decreases cost, energy, and pollution and increases quality, as shown in Table 4, Table 5 and Figure 5. The total Gap between P1- RCTCQEEBCT and without BCT is approximately 2.6%. Therefore, we suggest using and activating BCT to improve costs, quality, energy, and environment. This subject increases resiliency and sustainability in project management and increases responsibility and agility between pillars of projects.

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244

Table 4. Results of RCTCQEEBCT.

Problem	Objective function	Cost (Dollar)	Quality (%)	Energy (KWh)	Environment Co ₂ (Ton)	Activeting BCT
P1- RCTCQEEBCT	Cost	8178245.6	75.7%	1781493.9	8077062.3	Needed
	Quality	8340236.8	84.1%	1794838.5	7859241.5	Needed
	Energy	8299549.0	83.4%	1763188.4	8050137.5	Needed
	Environment	8761617.6	82.7%	1898758.6	6849198.2	Needed

Figure 5. Comparing P1- RCTCQEEBCT with BCT and without BCT

245

Table 5. Comparing P1- TCQEE with BCT and without BCT

Problem	Objective function	Cost (Dollar)	Quality (%)	Energy (KWh)	Environment Co ₂ (Ton)	Average GAP	Total Gap
P1- TCQEE without BCT	Cost	8206633.8	81.8%	1793305.2	8170535.2	2.6%	2.6%
	Quality	8469342.1	83.0%	1881500.2	8086856.2	2.0%	
	Energy	8336458.3	81.8%	1775985.6	8170145.1	0.2%	
	Environment	9644117.6	74.8%	2111692.6	7584523.6	5.6%	

246

247 **4.1. Variation on the Finish time**

248 As can be seen, we surveyed and changed finish time (T). When compacting finish time happens,
 249 costs, energy, and pollution environment increase, but quality decreases. It is entirely natural
 250 because by decreasing time, pushing project is occurred, therefore costs, energy, pollution
 251 environment increase, and finally we see decreasing quality (cf. Figure 6 and Table 6).

Figure 6. Variation on the Finish time.

252

Table 6. Variation on the Finish time.

Objective function	Finish Time (T)	Cost (Dollar)	Quality %	Energy (KW)	Environment Co ₂ (Ton)
Cost	29	8552016.0	83.0%	1887865.4	7252741.4
Cost	30	8459305.3	83.1%	1866733.2	7503325.8
Cost	32	8289252.6	83.3%	1792210.9	7892539.1
Cost	34	8178245.6	75.7%	1781493.9	8077062.3
Quality	29	8673150.0	83.6%	1891717.3	7228815.5

Quality	30	8598835.3	83.7%	1885109.7	7373318.5
Quality	32	8461071.4	83.9%	1859988.7	7596657.2
Quality	34	8340236.8	84.1%	1794838.5	7859241.5
Energy	29	8677357.1	83.0%	1855125.9	7262996.8
Energy	30	8577762.3	83.0%	1813109.3	7532145.2
Energy	32	8410127.7	83.3%	1773633.0	7911617.7
Energy	34	8299549.0	83.4%	1763188.4	8050137.5
Environment	29	8833879.3	82.8%	1912957.4	6992520.5
Environment	30	8817500.0	82.8%	1909739.0	6960034.1
Environment	32	8787812.5	82.7%	1903905.7	6901152.5
Environment	34	8761617.6	82.7%	1898758.6	6849198.2

4.2. Variation on the conservative coefficient

In this section, we do a variation on the conservative coefficient for decision-makers with risk-averse behavior until surveying the performance of mathematical model. If the conservative coefficient increases to 100%, the cost, energy and environment function functions grow and quality decrease (cf. Table 7 and Figure 7).

Figure 7. Variation on the conservative coefficient.

Table 7. Variation on the conservative coefficient.

Objective function	Conservative coefficient (β)	Cost	Quality	Energy	Environment
		(Dollar)	%	(KW)	Co ₂ (Ton)
Cost	25	8120021.4	80.2%	1764085.3	7993358.4
Cost	50	8178245.6	75.7%	1781493.9	8077062.3
Cost	75	8236469.9	82.9%	1798901.7	8160765.8
Cost	100	8294694.1	82.3%	1816310.1	8244469.6
Quality	25	8218302.6	84.4%	1783160.1	7826072.4
Quality	50	8340236.8	84.1%	1794838.5	7859241.5
Quality	75	8462171.1	83.8%	1806516.8	7892410.6
Quality	100	8584105.3	83.5%	1818195.2	7925579.7
Energy	25	8195886.0	84.0%	1753984.4	7953819.9
Energy	50	8299549.0	83.4%	1763188.4	8050137.5
Energy	75	8403212.0	82.9%	1772392.4	8146455.1
Energy	100	8506875.0	82.3%	1781596.4	8242772.7
Environment	25	8656691.2	83.3%	1879755.4	6803936.7
Environment	50	8761617.6	82.7%	1898758.6	6849198.2
Environment	75	8866544.1	82.2%	1917761.8	6894459.7
Environment	100	8971470.6	81.6%	1936765.0	6939721.2

4.3. Variation on a confidence level of CVaR

In this section, we do a variation on the confidence level of CVaR for decision-makers with risk-averse behavior until surveying the performance of mathematical model. If the confidence level of CVaR, change between 1% to 5%, the cost, energy and environment function functions grow up and quality is approximately not changed (cf. Table 8, Figure 8).

Table 8. Variation on the confidence level of CVaR.

Objective function	Confidence level (α)	Cost	Quality	Energy	Environment
		(Dollar)	%	(KW)	Co ₂ (Ton)
Cost	1%	8173760.8	75.7%	1781493.9	8077062.3
Cost	2%	8174847.7	75.7%	1781493.9	8077062.3
Cost	3%	8175957.0	75.7%	1781493.9	8077062.3
Cost	5%	8178245.6	75.7%	1781493.9	8077062.3
Quality	1%	8340236.8	84.1%	1794838.5	7859241.5
Quality	2%	8340236.8	84.1%	1794838.5	7859241.5

Quality	3%	8340236.8	84.1%	1794838.5	7859241.5
Quality	5%	8340236.8	84.1%	1794838.5	7859241.5
Energy	1%	8299549.0	83.4%	1762433.0	8050137.5
Energy	2%	8299549.0	83.4%	1762616.0	8050137.5
Energy	3%	8299549.0	83.4%	1762802.9	8050137.5
Energy	5%	8299549.0	83.4%	1763188.4	8050137.5
Environment	1%	8761617.6	82.7%	1898758.6	6845767.7
Environment	2%	8761617.6	82.7%	1898758.6	6846599.1
Environment	3%	8761617.6	82.7%	1898758.6	6847447.6
Environment	5%	8761617.6	82.7%	1898758.6	6849198.2

Figure 8. Variation on the confidence level of CVaR.

4.4. Variation on number of scenarios

In this section, we do a variation on the number of scenarios for surveying the performance of mathematical model. If the number of scenarios, change between 3 to 9, the cost function decrease.

Also, overall, quality and energy are declining and environment function is increasing (cf. Table 9, Figure 9).

Figure 9. Variation on the number of scenarios.

Table 9. Variation on the number of scenarios.

Objective function	Number of scenarios	Cost (Dollar)	Quality %	Energy (KW)	Environment Co ₂ (Ton)
Cost	3	8178245.6	75.7%	1781493.9	8077062.3
Cost	5	8176937.2	75.7%	1733430.9	8059719.8
Cost	7	8176306.9	75.6%	1765528.9	8082290.3
Cost	9	8175962.3	75.8%	1759858.0	8124934.2
Quality	3	8340236.8	84.1%	1794838.5	7859241.5
Quality	5	8334097.6	84.2%	1778489.7	7939402.5
Quality	7	8333143.3	84.1%	1811512.5	7902471.8
Quality	9	8331882.5	83.8%	1789442.6	7952332.0
Energy	3	8299549.0	83.4%	1763188.4	8050137.5

Energy	5	8298163.1	83.5%	1709604.8	8032065.5
Energy	7	8297664.5	83.4%	1736952.8	8056416.4
Energy	9	8297595.1	82.7%	1733996.7	8099405.6
Environment	3	8761617.6	82.7%	1898758.6	6849198.2
Environment	5	8760146.8	82.8%	1843622.9	6835339.5
Environment	7	8759516.4	82.7%	1878322.2	6842348.7
Environment	9	8759166.1	82.0%	1872062.9	6878632.9

4.5. Discussion

When we survey related work, we cannot see RCTCQEEBCT in the literature review. This mathematical model is the first time considered. In this section, we explore the RCTCQEEBCT in healthcare projects. We try to show the application of BCT in projects and show how it can help projects. We did sensitivity analysis on important parameters to show the performance of the model. Because of the difference between this research and the literature review, comparing with other related work is hard. This research is the development of Lotfi et al. (2020).

Eventually, we calculate RCTCQEEBCT. We analyze the finish time, the conservative coefficient, the confidence level of CVaR, and the number of scenarios. After solving the model, we receive these findings.

The total gap between RCTCQEEBCT and without BCT (Lotfi et al. (2020)) is approximately 2.6%. Therefore, using BCT in project management is completely useful. When compacting finish time happens or if the conservative coefficient increases to 100%, costs, energy, and pollution environment increase, but quality decreases. If the confidence level of CVaR change, the cost, energy and environment function functions grow up and quality is approximately not changed. Although, because of the difference between this research and the literature review, we cannot compare this research and try to compare only with Lotfi et al. (2020).

5. Managerial insights and practical implications

This research focuses on the applicability of BCT in project scheduling. We proposed a time-cost-quality-energy-environment tradeoff by considering BCT. Applying BCT make to decreases cost, energy, environmental (pollution) and increase quality. By using BCT, we can improve all objectives by 2.6%. We suggest that all project managers embed novel technology like BCT to their projects to improve the performance of activities.

In this research, we apply BCT as resiliency tools and consider resource constraints, relation of network pillar as agility tools. Moreover, utilizing BCT make to increasing resiliency, agility and sustainability in the project management area. Resiliency and flexibility in facing costs by doing activities short and increasing transparency in transaction and exchange with vendors and suppliers with agility. BCT can help project management on digital record storage, digital asset exchange, acceptable conduct assurance, reputation building, and intelligent contract execution. BCT changes the environment of projects from passive to active and can implement strategic projects in organizations.

Therefore, as managers of projects, we should move and apply novel technology in projects until resiliency, sustainability, and agility increase day by day. Apply and embed BCT in project management to increase resiliency and sustainability in project management and increase responsibility and agility between pillars of the project.

6. Conclusions and Outlook

The BCT is growing up day by day, and entrance in the life of humans and projects. Researchers and investors need to use it in their work. Therefore, we proposed to utilize BCT in project management to witness the efficiency as much as possible. In this research, we suggested using BCT and showed a mathematical model. We employed BCT as resiliency tools and considered resource constraints, relation of network pillar as agility constraints.

We used a hybrid robust optimization with considering a risk-averse approach for modeling TCQEE tradeoff. We applied weighted expected value, minimax and CVaR for all objective functions for robustness and risk-averse against disruption with the worst condition.

The findings of this research are as follows:

1. The results show that applying BCT decreases cost, energy, and pollution and increases quality, as shown in Table 4, Table 5 and Figure 5. Total Gap P1- RCTCQEEBCT and without BCT is approximately 2.6%. Therefore, we suggest using and activating BCT to improve costs, quality, energy and environment.
2. When compacting finish time happens, costs, energy, and pollution environment increase, but quality decreases. It is entirely natural because by decreasing time, pushing project is

occurred, therefore costs, energy, pollution environment increase, and finally we see decreasing quality (cf. Figure 6 and Table 6).

3. We analyze variation on the conservative coefficient for decision-makers with risk-averse behavior. If the conservative coefficient increases to 100%, the cost, energy and environment function functions grow and quality decrease (cf. Table 7 and Figure 7).
4. We do a variation on the confidence level of CVaR for decision-makers with risk-averse behavior. If the confidence level of CVaR increase, the cost, energy and environment function functions grow up and quality is approximately not changed (cf. Table 8, Figure 8).
5. Finally, we presented a variation on number of scenarios for surveying performance of the mathematical model. If the number of scenarios, change between 3 to 9, the cost function decrease. Also, overall, quality and energy are declining and environment function is increasing (cf. Table 9, Figure 9).

One of the research constraints is solving the model on a large scale. Because of the existence of MILP, we suggest using a new exact algorithm like Benders decomposition, Lagrange relaxation, and Column generation. Moreover, using heuristic and metaheuristic algorithms (Peng, Zhang, & Chen, 2021) is advantageous for solving in minimum time and gaining near-optimal solutions.

Embedding another method to cope with uncertainty like fuzzy, robust convex, and data-driven robust optimization is an exciting approach for the researcher. Using risk coherent risk criteria like Entropic Value at Risk (EVar), Robust Conditional Value at Risk (RCVaR) (Dixit & Tiwari, 2020; Li, Xin, Pardalos, & Chen, 2021) is a very excitable contribution.

Therefore, we proposed to utilize novel technology in project management like Internet of Thing (IoT), 3D printing and BCT to increase performance, resiliency, sustainability, and agility.

7. Ethical Approval

Not applicable

8. Consent to Participate

Not applicable

9. Consent to Publish

Not applicable

10. Authors Contributions

355 Reza Lotfi: conceptualization, supervision, software, methodology; software; formal analysis;
356 data curation; writing original draft; visualization;

357 Bahareh Kargar: methodology; software; formal analysis; data curation; writing original draft;
358 writing review and edit; visualization;

359 Alireza Gharehbaghi: methodology, validation;

360 Hanif Hazrati: validation, writing review and edit;

361 Sima Nazari: validation, writing review and edit;

362 Mohsen Amra: validation, writing review and edit;

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366 The authors declare no competing interests.

367 **13. Availability of data and materials**

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