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A Review of Resource-Constrained Project Scheduling Problems (RCPSP) Approaches and Solutions

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ABSTRACT

Resource-constrained project scheduling problems are one of the most famous proposed problems in operational research and optimization topic. Using of discrete models by considering complexity of the problems requires designing efficient algorithms for solving them. On the other hand, this series of topics and generally project management are given attention in recent decades. Competition features of today's world, lead in time implementation of project with required quality to be important. Those factors lead to be given attention to resource-constrained project scheduling problems and their solutions theoretically and practically by academic researches and practitioners. The purpose of the paper is determining different methods and approaches that are used for solving the mentioned problems simultaneously or separately. The various described models in literature that consist of more than 200 published papers in most well-known journals, are collected and proposed in table format. In this research by studying these papers, in addition clarifying features of the developed models and the gaps, practitioners of projects implementation in various organizations can choose appropriate model for their projects by considering organizational conditions, types of resources and their organization's activities' technological specifications.

1. Introduction

Project planning is determination of time sequencing or scheduling plan for conducting a series of related activities that are constituents of project. In this case, Project disintegrate to some activity by methods like work breakdown structure (WBS). These activities are connected with each other because there are various logical relations between them. Logical and Immediate relations between each two activities are explained by controller like Finish to start (FS) relation,

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start to start (SS) relation, finish to finish (FF) relation, and start to finish (SF) relation. Also, in more complicated projects it is possible to define more controllers like parallel implemented between two activities(Hadju, 1997In fact dependence of activities is based on their priority of implementation; it means it is possible that implementation of an activity depends on implementation of the others, this is called that project has priority constraints between activities. But in addition to these limitations, May bean other type of constraints, as resources constraints exist in project. So in project planning in addition to considering priority constraints, planning should be compatible with resources constraints. The objective of scheduling and sequencing activities is optimal allocation of limited resources over time. In fact scheduling is determination of activities which must be done in the specified time and sequencing, determine order of activities which must be done. Those project planning problems which do not have limitations of resources or consider them, are known as project scheduling problems without resource-constrained and those problems which have resource-constrained and these limitations are considered in planning project, called resource-constrained project scheduling problems (RCPSP). This problem is one of the most complicated problems of operation research which has considerable progress in developing exact solution and innovative methods at recent decades and recently new optimization methods are used to solve it" (Mohring et al, 2003).For implementing each activity requires different resources such as time, capital, human power and etc. These resources are often divided into two categories: Renewable like human power and non-renewable such as capital. Each activity can be implemented in several modes such as manually, semi-mechanized and mechanized. Implementation of each mood needs different type and amount of resources (Drexl et al, 1993). In resource-constrained project scheduling problems for implementing each activity like i needs r_{ik} unit of resource $k = 1,\dots,m$, at per unit of activity's execution time (d_i). Meanwhile k resource has b_k constraints per unit of time. The parameters (d_i ,r_i , b_k)are non-negative and determined. This problem's objective often is determining start time and mode of implementation of each activity for minimizing the project's execution time. It is obvious that the problem solution must provide constraints that are related to activities' logical relations, and consider resource constraints too. There are two optimal and heuristics approach for solving the problem (Herroelen et al, 1998). The realistic solution instances of the problem because of complexity, extension and difficulty with optimal approaches like mathematical planning, dynamic planning or branch and bound, is impractical (Brucker et al, 1998).

2. Solving Methods

Before suing of computer in project scheduling problems, researches scheduled projects manually so it was too time consuming and was not a good guaranty for achieving an optimal result. In the last of 1950 decade, developing critical path techniques and evaluating and overlooking the project led that projects had capability to be described by network diagrams as works and activities were defined by network structure. Nevertheless, within the techniques, only time was considered and limitation of using resources was not studied. Meanwhile project's constraint is one of the main problems of project planning in real world, during two recent decades types of project scheduling planning techniques under resource constrained conditions were proposed, implemented and controlled which generally are divided to exact and approximate methods. In fact it can be told that resource-constrained project scheduling problem has more than 40 years history. There are two approaches, optimal and heuristics, for solving the problem (Herroelen et al, 1998). Each of the methods has disadvantages and advantages. The exact methods have ability to obtain and guaranty optimal result. In these methods, all solving problem spaces are searched to find optimal answer from solving space. Although essential calculations for these methods are so many and as a results, they are so slow but guaranty the general optimization of problem, in fact the realistic solution instances of the problem because of complexity, extension and difficulty with optimal approaches like mathematical planning, dynamic planning or branch and bound, is impractical (Brucker et al, 1998). Of course the application of optimal approaches for solving smaller instances of the problem are reported in the literature. For instance, the paper refers interested reader to (Deckro et al, 1991) about mathematical planning, to (Icmeli et al, 1996. Carruthers et al, 1996) for numerical methods such as dynamic planning, to (Petrovic 1968, Demeulemeester 1998) about branch and bound methods. And for overcoming the computational problems of the methods, approximate methods are proposed. In these methods, Instead of the whole space of problem solution, a part of it is searched so they do not guaranty the optimal results and try to achieve a good approximate answer but they are quick methods and at the right time they achieve a good answer for huge problems. Many of the heuristics solving approaches for resource-constrained project scheduling problems are studied at 2006 (Kolisch et al, 2006). They categorized the approaches in 4 groups as (1) Priority rule- based approaches like Random sampling (Coelho et al, 2003); (2) Approaches based on meta-heuristics methods such as genetic algorithm (Alcaraz et al, 2003. Tareghian et al, 2007), tabu search algorithm (Nonobe et al, 2002), simulated annealing (SA) algorithm (Valls et al. 2004) ant systems (Merkle et al, 2002); (3) Non – Standard meta-heuristics approaches like scatter search algorithm (Fleszar et al, 2004); and at last (4) approaches based on other heuristics methods such as forward and backward Improvement (FBI) (Tormos et al. 2003), Network analysis (Sprecher, 2002). This paper categorizes solving models that are discussed in past literature, as 3 diagrams

3. Exact solving methods

RCPSP are as general format of sequence of operations of NP hard problems type. The

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optimal solutions, which are mentioned in literature, are: Zero-one mathematical planning and numerical implicit methods such as dynamic planning and branch and bound method. At recent decades, solving the problems is improved widely which are tested in two series problem. These series are: Series of 110 problems designed by Peterson and Series of 480 problems by Klisch. Algorithms are evaluated base on how many problems are solved by them at how much time. The series of Peterson problems include 110 problems instances that are designed by Peterson. Series of problems have 7 to 50 activities and 1 to 3 renewable resources. During last decades, this series was a criterion for evaluating validity and ability of optimal and close to optimal procedure. In 1995, Klisch questioned validity of Peterson's series that leads to develop ProGen. Network producer software that is able to produce RCPSP pattern with pre-determinate and 30 types of activity and 4 types of renewable resource, see Figure 1.

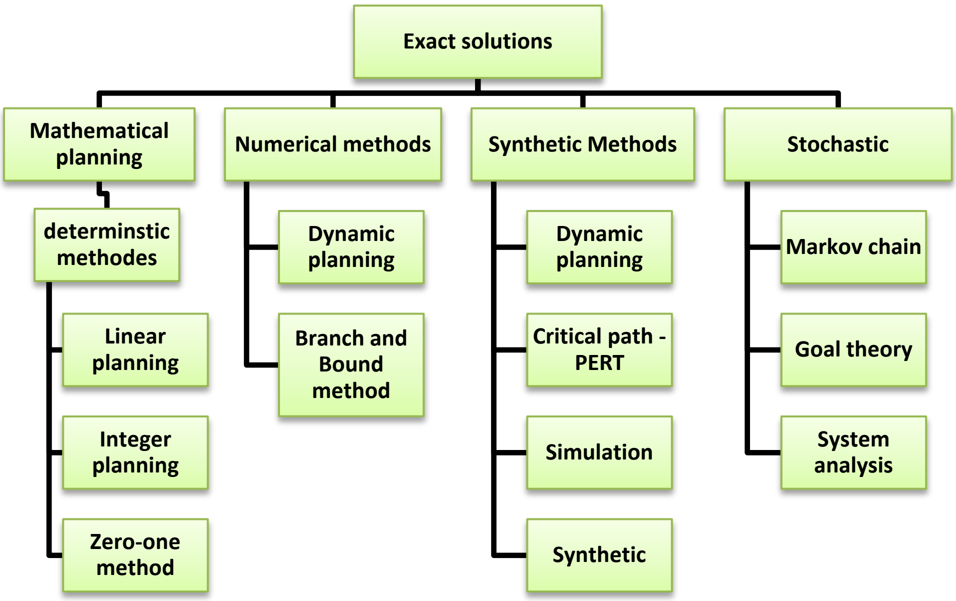

Figure 1: Exact solution categories

3.1 Heuristics solutions

A brief definition of a heuristics method is a technique that search close solutions to optimal with acceptable computational cost, but in fact unlike the exact solutions which guaranty finding the optimal answer if there are, they do not guaranty for achieving to an optimal result. Heuristics methods sometimes find the optimal answer and most of the time they reach to good answer. And these methods usually require less time and memory than exact solutions. The heuristics in scheduling often are defined as scheduling rules with dispatch rules. Often the rules are complex to be defined and for a specific type of the problem with a special series of restrictions and assumptions, are appropriate. The heuristics are used for searching combinational space of permutations in sequences of tasks or determining the conceivability of allocating resource, time and task during creation of scheduling or combining sequencing and scheduling. Heuristics scheduling are applied on series of tasks and determine at what time which task must be done. If a task can be done in more than one implementation condition or on series of resources, heuristics determines which resource or implementation is used. The heuristics solutions are be used for major problems pattern.

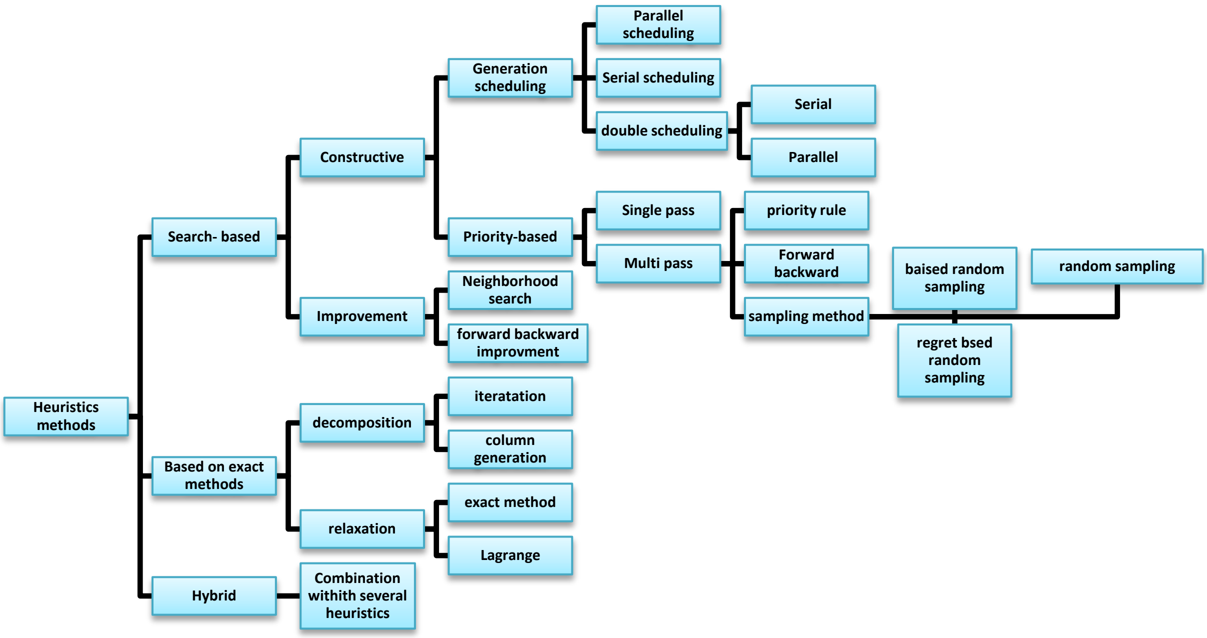

Figure 2: Heuristics methods categories

3.2 Meta-heuristics Solutions

During last 20 years, a new type of estimated algorithm has been created which essentially tries to combine basis heuristics methods with an objective of efficient and effective search in search space in frameworks of upper level. The meta-heuristics methods are the last generations of heuristics algorithms and widely used for solving RCPSP too. In fact, the meta-heuristics are strategies in order to guiding search process. Participant techniques in meta-heuristics algorithms are in range of simple procedure, local search to complex learning processes.

3.2.1 Trajectory Methods

It works on single solutions and includes meta-heuristics based on local search. It means that algorithm start form primary condition (primary solution) and describes a trajectory in search space. Each movement is take place if the result solution is better actual one. Upon finding local minimal, the algorithms end such as Tabu search, iterated local search and variable neighborhood search. Their common features are describing a trajectory in search space during search process.

3.2.2 Population methods

They do search process which combine meta-heuristics evolution with exact methods or

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other meta-heuristics, and combination of types of heuristics and meta heuristics in order to achieving optimal answers, can be observed in meta-heuristics methods, Figure 3.

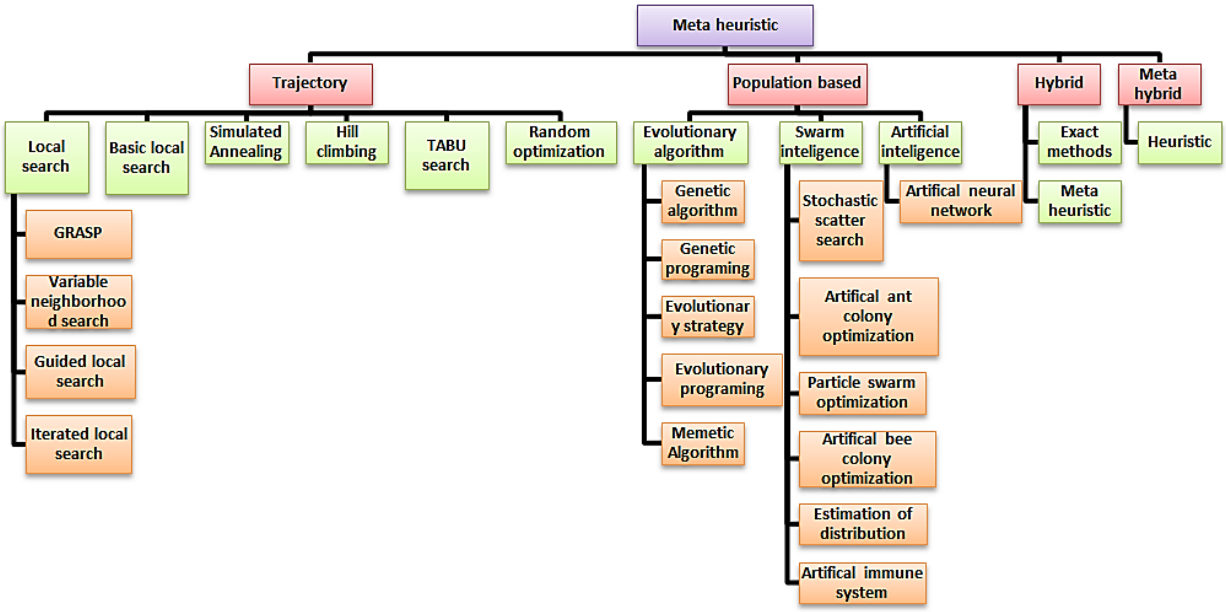

Figure 3: Meta Heuristics methods categories

4. Approaches

Most of the studies in planning and project scheduling assume that there are complete information for solving scheduling problem which must be solve and the obtained basis scheduling plan will be implemented in a static environment too. Although there are many uncertainly in a relation with activities implementation that take place with implementation of project gradually which includes the following categories in diagram? In this section, there is review of basis approaches in project planning and scheduling at exact and unreliability conditions. It will be discussed about application potential of each of the methods in project uncertainly planning with definitive network structure. Figure 4 show types of RCPSP approaches.

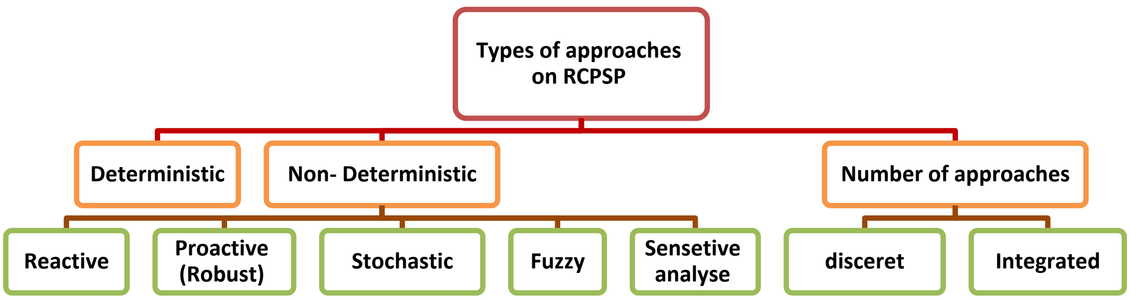

Figure 4: Types of RCPSP approaches

4.1 Deterministic approach

In this approach, all problems' parameters are assumed definitive and determined and it has rich position in RCPSP literature and is used for relaxation of the assumption in most of the papers. These kinds of papers because of simplifying real conditions have defects and practically, restrict efficiency of model in real projects.

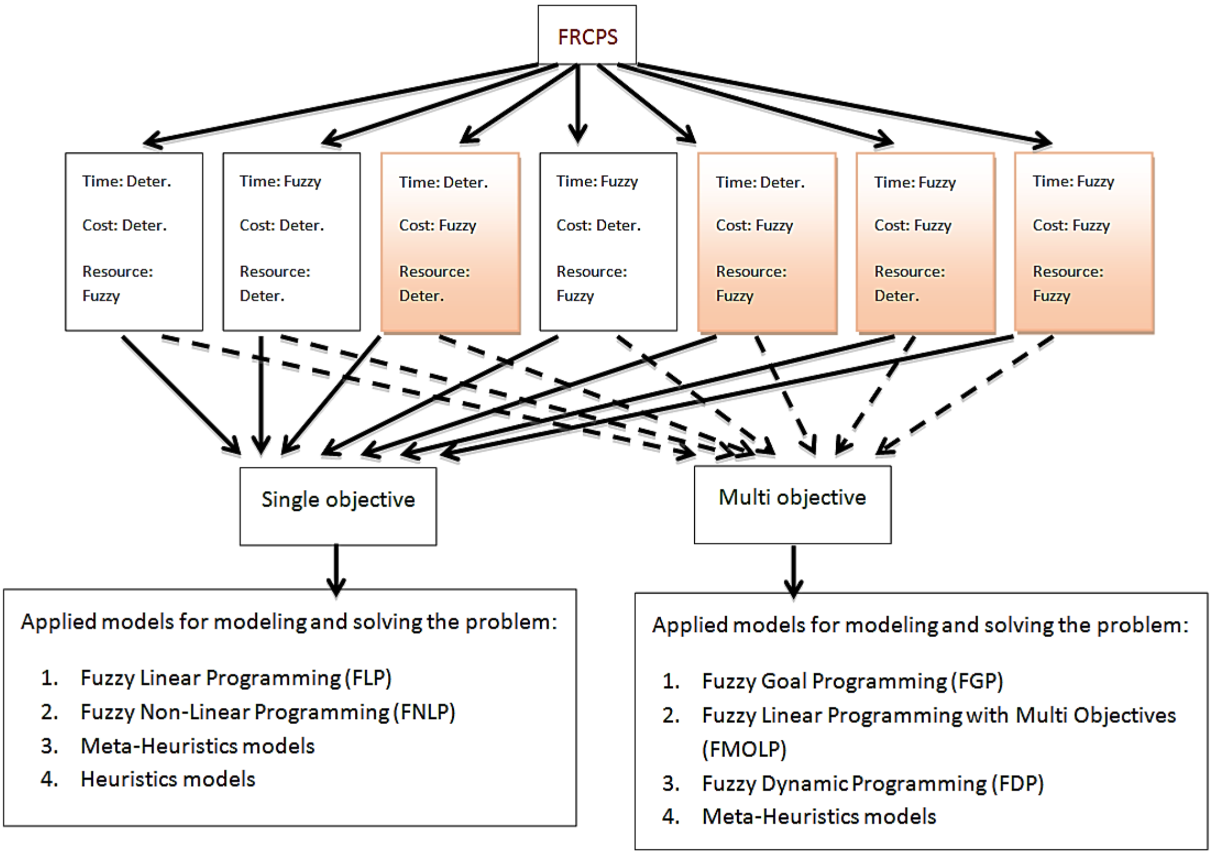

Figure 5: FRCPSP categories.

4.2 Proactive (Robust) approach

Objective of the proactive scheduling is producing basis-scheduling stable so in order to be protected against interruptions during implementation of project. Temporary protections (Gao 1995)increase duration of activities based on unreliability of amount of resources, which are used for activities. Resources that have possibility of failure or violation are called probable to violation resources. Protected duration of the activity includes main duration added to waiting duration of violation. Then basic scheduling is provided by problem solution with protected durations.

4.3 Reactive approach

In Reactive scheduling, uncertainly are not given attention at creating basis scheduling but when uncertainly occur, the approach tries to answer, correcting and re-optimize the basis scheduling. Generally, the approach's main correction is on correcting and optimizing the basis scheduling if unanticipated events are occurred. The basis scheduling can be designed based on various strategies. On the other hand, answering to occurred changes can be based on very

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simple techniques such as Right shift rule (Sadeh et al. 1993) that they are influenced because of the defect in resources or precedence relations, transferred to the right which means their implementation time are postponed, it's obvious that the method is not a such good idea because it does not reschedule. The similar strategies are called schedule repair actions.

4.4 Fuzzy approach

Fans of activity ambiguous express the probability distribution function of activities leads to ambiguity and imprecise of estimation. The probability distribution function of an activity is ambiguous as long as information of its past, was not gained. A human expert should estimate the probability distribution function of an activity that often is non-recurring and exclusive.

4.5 Stochastic project approach

Objective of stochastic project scheduling with resource constrained, is project scheduling which is such that despite of activity duration uncertainly, precedence relations (Finish to start with zero lag) and renewable resource-constrained, minimizes make span. The studies on stochastic project scheduling are partly sporadic. Most of the studies are known as "stochastic project scheduling with resource-constrained" which are studied in next section.

5. Review of Solutions and Approaches of Resource-constrained Project Scheduling

In order to review researches procedure and researches' opportunities, all of the researches are studied as two perspectives " solution methods and approaches" in more than 200 papers of valid journals and after removing the similar articles, the chosen articles was studied and extracted their points and the results are shown by following tables. Tables 1 and 2 show the results of research about types of solution methods and approaches in RCPCP literature. There are brief explanations about important results of research in considerations column.

Table 1: RCPSP researches based on solution methods

	Authors	Year	Solutions				Specifications
			Exact method	Not exact method			
				Heuristics	Meta heuristics	Other	
1.	D.C. Paraskevopoulos et al.	2012		AILS, SAILS			Propos solution methodology, namely SAILS, operates on the event list and relies on a scatter search framework. The latter incorporates an Adaptive Iterated Local Search (AILS), as an improvement method, and integrates an event-list based solution combination method.
2.	Chen Fang, Ling Wang	2012		SSGS	SFLA		Encode the virtual frog as the extended activity list (EAL) and decode it by the SFLA-specific serial schedule generation scheme (SSSGS) and To enhance the exploitation ability, a combined local search including permutation-based local search (PBLS) and forward–backward improvement (FBI) is performed.
3.	Mohamed Haouari et al	2012	Dynamic programming, lower				Propose three classes of lower bounds that are based on the concept of Enhanced energetic reasoning

			bounds				
4	Ling Wangn, ChenFang	2012		SSGS, MFBI, MPBLS	EDA		In the EDA the individuals are encoded based on the activity-mode list (AML) and decoded by the multi-mode serial schedule generation scheme (MSSGS), and a novel probability model and an updating mechanism are proposed for well sampling the promising searching region.
5	Thomas S. Kyriakidis et al.	2012	MILP				Present new mixed-integer linear programming models
6	KoorushZiarat i etal.	2011		SSGS	Bee algorithms		Proposed algorithms iteratively solve the RCPSP by utilizing intelligent behaviors of honeybees. Each algorithm has three main phases: initialization, update, and termination.
7	Shu-Shun Liu& Chang-Jung Wang	2011	CP				A generic model is proposed to maximize the total profit of selected projects for construction and R&D departments given scheduling problems with various resource constraints during specified time intervals
8	FilipDeblaere et al.	2011		Simulation -based Descent (SBD),			The procedure is basically a combination of four descent procedures that use simulation to evaluate the objective function
9	SiamakBarada ran et al.	2011		SSGS	HMA		Presents a hybrid met heuristic algorithm based on scatter search and path linking algorithms to solve the stochastic MRCPSP
10	Mohammad Ranjbar et al.	2011	Branch-and-bound algorithm				Present a branch-and-bound algorithm in which the branching scheme starts from a graph representing a set of conjunctions In the search tree; each node is branched to two child nodes based on the two opposite directions of each undirected arc of disjunctions.
11	R. Čapek et al	2011	Linear programming model	IRSA			A heuristic algorithm based on priority schedule construction with an un-scheduling step is proposed for the nested version of the problem and it is used to solve the case study of the wire harnesses production.
12	MariemTrojet et al.	2011	CP				Provide a decision support framework under the constraints as a margin of cooperation/ negotiation with subcontractors
13	Ling Wang, Chen Fang	2011		SSGS	Hybrid EDA (HEDA)		Individuals are encoded based on the extended active list (EAL) and decoded by serial schedule generation scheme (SGS), a Forward–Backward iteration (FBI) and a permutation based local search method (PBLS) are incorporated into the EDA based search to enhance the exploitation ability
14	José Coelho, Mario Vanhoucke	2011			A novel meta-heuristic		The algorithm splits the problem into a mode assignment step and a single mode project-scheduling step. The mode assignment step is solved using a fast and efficient SAT solver.
15	Ruey-Maw Chen	2011		SSGS	JPSO		The justification technique is combined with PSO as the proposed justification particle swarm optimization (JPSO), which includes other designed mechanisms.
16	Shanshan Wu et al.	2011		SSGS	CBIIA		The proposed CBIIA is based on the traits of an artificial immune system, chaotic generator and parallel mutation
17	Mahdi Mobini et al.	2011		SSGS	AIA		The proposed algorithm benefits from local search mechanisms as well as mechanism that enhances the diversity of the search directions
18	OumarKone et al.	2011	MILP				Make a comparative study of several-mixed integer linear programming (MILP) formulations for resource-constrained project scheduling problems (RCPSPs).
19	LucioBianco& Massimiliano Caramia	2011	Lower bound				The lower bound is based on a relaxation of the resource constraints among independent activities and on a solution of the relaxed problem suitably represented by means of an AON acyclic network.
20	Agustín Barrios et al.	2011		DGA			The heuristic is a two-phased genetic algorithm with different representation, fitness, crossover operator, etc., in each of them.
21	AnuragAgarw	2011				Neurogene	A new hybrid of a neural network approach and the genetic

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	al et al.					tic approach	algorithms approach
22.	Francisco Ballestıín, RosaBlanco	2011		SSGS	SPEA2, NSGA2 and PSA		Extensive computational results help decide which algorithms or techniques are the most promising for the problem.
23.	FilipDeblaere et al.	2011	Branch-and-bound	IDA	TS		Propose and evaluate a number of dedicated exact reactive scheduling procedures as well as a TABU search heuristic for repairing a disrupted schedule
24.	TarunBhaskar et al.	2011		SPI			Propose a non-recursive heuristic method based on priority rule for a new scheduling scheme and call it priority rule as Schedule Performance Index
25.	GrzegorzWaligóra	2011		DCSGS	Heuristic HUDD-PS		Different approaches to solving the continuous part of the problem were presented an exact approach requiring solving a convex mathematical programming problem, a heuristic approach to the continuous resource allocation problem (heuristic HUDD-PS), and the approach based on the continuous resource discretization.
26.	José Fernando Gonçalves et al.	2011		FBI, SSGS	Genetic algorithm		Active schedules are constructed using a priority-rule heuristic in which the priorities of the activities are defined by the genetic algorithm. A forward-backward improvement procedure is applied to all solutions.
27.	Vincent Van Peteghem, Mario Vanhoucke	2011		SSGS	Scatter search algorithm		Combination of improvement methods and the introduction of two local searches into one overall solution procedure leads to promising computational results
28.	Reza Zamani	2011		SSGS	A hybrid decomposition procedure		The procedure finds an initial schedule for the project, and refines it through a decomposition process, To achieve further reduction, the refined schedule is over-refined by a genetic algorithm
29.	Olivier Lambrechts et al.	2011		Time buffering using the STC			Suggest to either implement time buffering based on the first surrogate objective function or using the STC heuristic
30.	BehzadAshtiani et al.	2011		SSGS, local-search			A two-phase local-search procedure is developed to produce high-quality pre-processor policies for SRCPSP instance, first phase is devoted to finding good priority lists
31.	Francisco Ballestín et al.	2011		SSGS, evolutionary algorithm			Works on a population consisting of several distance-order-preserving activity lists representing feasible or infeasible schedules. The algorithm uses the conglomerate-based crossover operator
32.	Jie Zhu et al.	2011			Genetic algorithm		During the genetic process of the proposed GA, an offspring generator was introduced to generate a feasible activity list from parent chromosomes
33.	Mohammad Jaberi	2011		SSGS		Potts-MFA	A Potts mean field feedback artificial neural network is designed and integrated into the scheduling scheme so as to automatically select the suitable activity for each stage of project scheduling
34.	Hong Zhang,Feng Xing	2010			PSO	FLC	Present a fuzzy-multi-objective particle swarm optimization to solve the fuzzy TCQT problem. The time, cost and quality are described by fuzzy numbers and a fuzzy multi-attribute utility methodology incorporated with constrained fuzzy arithmetic operations is adopted to evaluate the selected construction methods
35.	E. Klerides, E. Hadjiconstantinou	2010		Two-stage stochastic integer programming			Propose a path-based two-stage stochastic integer programming approach in which the execution modes are determined in the first stage while the second stage performs activity scheduling according to the realizations of activity durations
36.	Qi Hao et al.	2010		A dynamic algorithm			A dynamic algorithm based on partial task networks ,practical heuristics for conflict detection, project prioritization and conflict resolution
37.	Svio B. Rodrigues, Denise S. Yamashita	2010		MMBA algorithm			The new algorithm consists of a hybrid method where an initial feasible solution is found heuristically
38.	Sonda Elloumi, Philippe	2010			A hybrid rank-based evolutiona		Introduce clustering algorithms to compute densities. In this way enforce that neighbor solutions belong to the same cluster and are assigned the same density.

	Fortemps				ry algorithm		
39	AnisKooli et al.	2010	Integer programming				New feasibility tests for the energetic reasoning are introduced based on new integer programming (IP) formulations.
40	Jairo R. Montoya-Torres et al.	2010		SSGS, PSGS	genetic algorithm		Propose an alternative representation of the chromosomes using a multi-array object-oriented model in order to take advantage of programming features in most common languages for the design of decision support systems
41	SiamakBaradaran et al.	2010		SSGS, PSGS	A hybrid scatter search		The path re-linking algorithm and two operators like crossover and prominent permutation-based are applied to solve the problem
42	Moslem Shahsavar et al.	2010			Genetic algorithm		Genetic algorithm (GA) is designed using a new three-stage process that utilizes design of experiments and response surface methodology.
43	C.U. Fündeling, N. Trautmann	2010		A novel method of SGS			Present a priority-rule method based on a novel schedule-generation scheme and a consistency test for efficient scheduling of individual activities that iteratively determines a feasible resource-usage profile for each activity
44	Ruey-Maw Chen et al.	2010			A novel PSO		The delay local search enables some activities delayed and altering the decided start processing time. The bidirectional scheduling rule which combines forward and backward scheduling to expand the searching area in the solution space for obtaining potential optimal solution.
45	Wang Chen et al.	2010		SSGS	ACOSS		Algorithm combines a local search strategy, ant colony optimization (ACO), and a scatter search (SS) in an iterative process
46	Vincent Van Peteghem, Mario Vanhoucke	2010		SSGS	GA		Apply a bi-population genetic algorithm, which makes use of two separate populations and extend the serial schedule generation scheme by introducing a mode improvement procedure.
47	E. Klerides, E. Hadjiconstantinou	2010	Integer programming				Propose a path-based two-stage stochastic integer programming approach in which the execution modes are determined in the first stage while the second stage performs activity scheduling according to the realizations of activity durations
48	Andrei Horbach	2010	Lower bounds				Solver is lightweight and shows good performance both in finding feasible solutions and in proving lower bounds
49	Angela H. L. Chen, Chiuh-Cheng Chyu	2010	Branch-and-bound		The two-phase hybrid metaheuristic		Using a branch-and-bound algorithm to solve the mode assignment problem in the first phase; then, by transforming a multi-mode case into a single-mode problem, the second phase was activated and the memetic algorithm was applied to achieve good quality solutions
50	WANG Hong et al.	2010		SSGS, PSGS, FBI	GA		Algorithm employs a standardized random key (SRK) vector representation with an additional gene that determines whether the serial or parallel schedule generation scheme (SGS) is to be used as the decoding procedure. The iterative forward-backward improvement as the local search procedure is applied upon all generated solutions
51	Reza Zamani	2010		Parallel complete anytime procedure			Procedure finds a sequence of solutions in which every solution improves the previous one. To accelerate the convergence of the sequence to the optimal solution, the procedure simultaneously works in the forward and backward directions
52	JiupingXu&Zhe Zhang	2010			Hybrid genetic algorithm	FLC	Choose the hybrid genetic algorithm (HGA), and apply fuzzy logic control (FLC) to hybrid genetic algorithm (FLC-HGA) for enhancing the optimization quality and stability
53	Isabel Correia et al.	2010		Upper bound			A mixed-integer linear programming formulation, proposes a two-phase heuristic procedure for obtaining such bound. In the first phase, a feasible schedule is constructed. In the second phase, an attempt is made to improve this schedule by means of a local search procedure.
54	Wang Xianggang1 & Huang Wei	2010				Hybrid intelligent algorithm	Hybrid intelligent algorithm integrated by genetic algorithm and fuzzy simulation is designed to solve the above two fuzzy programming models.

55.	H. R. Yoosefzadeh et al.	2010	PSGS	Priority Rules			Compared the performance of forward, backward, bidirectional and tri-directional planning schemes in the context of different priority rules, The result obtained by each combination is an upper bound (UB) on the optimal project duration
56.	Angelo Oddi et al.	2010			Different flattening algorithms within the ifs meta-heuristic strategy		Iterative flattening search (ifs) is a meta-heuristic strategy for solving multi-capacity scheduling problems. Given an initial solution, ifs iteratively applies: a relaxation-step, and a flattening-step
57.	Doreen Krüger& Armin Scholl	2010		Mixed-integer model			At first develop a framework for considering resource transfers in single- and multi-project environments. Afterwards, define the multi-project scheduling problem with transfer times (RCMPPTT) and formulate it in a basic and an extended version as integer linear programs Eventually, it is supplemented for the first time by cost considerations
58.	YuryNikulin& Andreas Drexl	2010			Pareto Simulated Annealing		A multi-criteria meta-heuristic, in order to get a representative approximation of the Pareto front
59.	Tyson R. Browning &Ali A. Yassine	2010			A random generator		Present the first multi-network problem generator, The generator produces “near-strongly random” networks quickly, and can produce increasingly more strongly random networks at greater computational expense. Then identify a tradeoff between the degree of randomness and computational time
60.	Fawaz S. Al-Anzi et al.	2010		Lower bound			A lower bound that uses a linear programming scheme for the RCPSP.
61.	M. Ranjbar& F. Kianfar	2010		SSGS, a local search	GA		Developed a linear model for the problem, an enumeration procedure for generation of feasible work problems and a meta-heuristic, based on the Genetic Algorithm (GA), for solving the problem. Also developed a local search incorporated with GA to improve the solutions' quality
62.	N. Damak et al.	2009			Differential evolution (DE) algorithm.		Focus on the performance of this algorithm to solve the problem within small time per activity.
63.	PengWuliang, Wang Chengen	2009			Improved genetic algorithm		According to the characteristics of the proposed problem, an improved genetic algorithm was presented
64.	Liang Yan et al.	2009		New heuristic approach			Combining the RCPSP model with the five heuristic, By comparing with those generated by the manual decision-making method, the results generated by heuristic algorithm indicate high efficiency
65.	Po-Han Chen, Seyed Mohsen Shahandashti	2009			Hybrid of GA-SA		First attempts to use meta-heuristics and non-traditional techniques, can be seen that GASA Hybrid has better performance than GA, SA, MSA, and some most popular heuristic methods
66.	Po-Han Chen,HaijieWeng	2009			Two-phase GA (genetic algorithm)		The developed two-phase GA model works well. With further development to allow for multiple resource types, the two phase GA model could be generalized and applied to all sorts of resource-constrained project scheduling problems, including interruption and overlap of activities
67.	VikramTiwari et al.	2009	IP				Formulate the problem with a rework, quality-enhancing component and solve the resulting problem using commercial optimization procedures.
68.	Jiaqiong Chen, Ronald G. Askin	2009	MIP				Two versions of the Mixed Integer Program (MIP)
69.	Mohammad Ranjbar et al.	2009		SSGS	A hybrid scatter search		Using path re-linking methodology as a solution combination method.
70.	Antonio Lova et al.	2009		SSGS, PSGS	a hybrid Genetic Algorithm (MM-HGA)		A new parameter has been designed and its efficiency stated. In the evolution process characteristic of the GAs, fitness function plays a crucial role

71.	J.J.M. Mendes et al.	2009			A random key based genetic algorithm		The schedule is constructed using a heuristic priority rule in which the priorities of the activities are defined by the genetic algorithm.
72.	Kuo-Ching Ying et al.	2009			A hybrid–directional planning scheme		To evaluate the effectiveness of the proposed scheme, different planning directions are incorporated into some meta-heuristics, including GA, SA, and TS
73.	WU Yu et al.	2009			Timed colored Petri net (TCPN)		Firstly a novel mapping mechanism between traditional network diagram such as CPM (critical path method)/PERT (program evaluation and review technique) and TCPN was presented
74.	JörgHomberger	2011		CMAS			Multiple solutions consists of several self-interested schedule agents, each of which plans a single project decent rally and autonomously.
75.	C.C. Chyu& Z.J. Chen	2009		Several variable neighborhood search (VNS)algorithms			Developed by using insertion move and two swap to generate various neighborhood structures, and making use of the well-known backward–forward scheduling, a proposed future profit priority rule, or a short-term VNS as the local refinement scheme (D-VNS).
76.	M. D. Mahdi Mobini et al.	2009		SSGS, PSGS	Enhanced scatter search		Decode to the solutions using both serial and parallel SGS and serial-SGS was used during the iterations of the algorithm. In the proposed ESS, three operators were used to generate new solutions from existing solutions in the reference set
77.	Christian Artigues& Cyril Briand	2009			A new polynomial algorithm		As a basic search framework For reinsertion neighborhoods
78.	Shu-Shun Liu,Chang-Jung Wang	2008		CP			Presented model, constructed by Constraint Programming (CP), considers resource usage and cash flow in project scheduling to fulfill management requirements.
79.	Nai-Hsin Pan et al.	2008			An improved TS model		Develop an improved TS model by modifying the way of finding a starting solution instead of traditional TS algorithm, minimum moment algorithm (MMA)
80.	Stijn Van de Vonder et al.	2008		PSGS, RFDFF, VADE, STC			Multiple efficient heuristic and meta-heuristic procedures are proposed to allocate buffers throughout the schedule
81.	Francisco Ballestı´n et al.	2008		SSGS, DJGA, 1_DJGA			show how three basic elements of many heuristics for the RCPSP – codification, serial SGS and double justification – can be adapted to deal with interruption
82.	R. Alvarez-Valdes et al.	2008		Several heuristic algorithms			Procedures. Heuristic algorithms based on GRASP and Path re-linking are then developed and tested on existing test instances
83.	J.F. Gonçalves et al.	2008		SSGS	GA		Schedules are constructed using a heuristic that builds parameterized active schedules based on priorities, delay times, and release dates defined by the genetic algorithm
84.	Hédi Chtourou& Mohamed Haouari	2008		Two-stage-priority-rule-based			The first stage solves the RCPSP for minimizing the makespan only using a priority-rule-based heuristic, namely an enhanced multi-pass random-biased serial schedule generation scheme. Then similarly solved for maximizing the schedule robustness while considering the makespan obtained in the first stage as an acceptance threshold.
85.	Haitao Li, Keith Womer	2008		Constraint programming			A constraint programming (CP) based solution approach is proposed and implemented in one case study
86.	LuongDuc Long, ArioOhsato	2008			Developed a procedure (named P1)		The proposed method is useful for both project planning and execution which is well known priority heuristic rules and standard genetic algorithm
87.	Mohammad Ranjbar	2008		a new heuristic algorithm			Proposes a new heuristic algorithm for this problem based on filter-and-fan method incorporated with a local search, exploring in the defined neighborhood space

88.	Marek Mika et al.	2008		SSGS	TS		An application of a local search meta-heuristic TABU search for the considered problem has been described
89.	Mario Vanhoucke	2008	Branch-and-bound				First aim at the construction of efficient meta-heuristic solution procedures to solve the PRCPSP-FT and the PDTRTP-FT where set-up times are incorporated between pre-emptive sub-activities, Second try to extend this approach to a flexible activity assumptions problem setting
90.	Shih-Tang Lo et al.	2008			ant colony optimization (ACO)		Present a modified ACO approach named DDACS for a multi-constraint multiprocessor scheduling problem The proposed DDACS algorithm modifies the latest starting time of each job in the dynamic rule for each iteration
91.	Vicente Valls et al.	2008		SSGS	Hybrid Genetic Algorithm (HGA)		HGA introduces several changes in the GA paradigm: a crossover operator specific for the RCPSP; a local improvement operator that is applied to all generated schedules a new way to select the parents to be combined; and a two-phase strategy by which the second phase re-starts the evolution from a neighbor's population of the best schedule found in the first phase.
92.	L.-E. Drezet, J.C. Billaut	2008	MILP formulation	Two-phase heuristic algorithm			The first phase is a greedy algorithm, whose solution is used in the second phase as an initial solution for a TABU search algorithm
93.	Mario Vanhoucke, Dieter Debels	2008	Branch-and-bound				Present adapted lower bound and upper bound calculations for the PDTRTP-FT.
94.	B. Jarboui et al.	2008			Combinatorial PSO (CPSO) algorithm		CPSO algorithm outperforms the simulated annealing algorithm and it is close to the PSO algorithm. Also used a local search method to optimize the sequence associated to each assignment.
95.	Sanjay Kumar Shukla et al.	2008		SSGS	Adaptive sample-sort simulated annealing	FLC	Propose a parallel intelligent search technique named the fuzzy based adaptive sample-sort simulated annealing (FASSA) heuristic. The basic ingredients of the proposed heuristic are the serial schedule generation scheme (SGS), sample sort simulated annealing (SSA), and the fuzzy logic controller (FLC).
96.	Olivier Lambrechts et al.	2008		SSGS	Time slack-based techniques, TS		Develop an approach for inserting explicit idle time into the project schedule in order to protect it as well as possible from disruptions caused by resource un-availabilities.
97.	Olivier Liess& Philippe Michelon	2008		Constraint programming			Classical Constraint Programming approach for the (RCPSP) except that the timetable algorithm is not considered.
98.	A. A. Lazarev& E. R. Gafarov	2008	Branch-and-bound				Prove that method like branch-and-bound (branch & bounds, Constraint Programming, and so on) with the lower estimate LBM be ineffective.
99.	MajidSabzehparvar& S. Mohammad Seyed-Hosseini	2008	Linear mixed integer programming				Time horizon can be continuous in this model thus dealing with different processing time units
100.	Jean Damay et al.	2007	Linear programming				A time-indexed linear formulation of the non-preemptive version of the RCPSP involving these feasible subsets
101.	ShahramShadrokh, FereydoonKianfar	2007			GA		690 problems are solved and their optimal solutions are used for the performance tests of the genetic algorithm
102.	Mohammad R. Ranjbar, FereydoonKianfar	2007	SSGS		Ameta-heuristic algorithm		Based on the genetic algorithm and a new method based on the resource utilization ratio is developed for generation of crossover points and also a local search method is incorporated with the algorithm
103.	JirachaiBuddhakulsomsi, David S. Kim	2007		SSGS, Priority rule-based			Both deterministic multi-pass and stochastic multi-pass heuristics have been constructed
104.	Stijn Van de Vonder et al.	2007		SSGS, PSGS, weighted-			Present a sampling procedure that combines the schemes with multiple priority lists. Also describe a heuristic for the weighted earliness–tardiness problem

				earliness tardiness heuristic			
105.	Jacques Carlier& Emmanuel Néron	2007			Enumeration algorithm		Propose an explicit enumeration of the redundant resources and a characterization of the non-dominated ones
106.	M. Rabbani et al.	2007		A new heuristic algorithm			In order to prevent creating a lower bound for the mean project completion time, the most critical chain is determined and its standard deviation is added to project completion time as the project buffer
107.	VéroniqueBouffard& Jacques A. Ferland	2007			Improving simulated annealing with variable neighborhood search		Consistent with the fact that the simulated annealing approach performs better than the TABU search approach for RCPSP Furthermore, the performance of the simulated annealing method can be improved with a variable neighborhood search approach
108.	RinaAgarwal et al.	2007				Artificial immune system	The performance of the proposed AIS algorithm on test problem, reported in literature is found to be superior, when compared with GA, fuzzy-GA, LFT, GRU, SIO, MINSLK, RSM, RAN, and MJP
109.	Lin-Yu Tseng, Shih-Chieh Chen	2006			A hybrid meta heuristic ANGEL		ANGEL combines ant colony optimization (ACO), genetic algorithm (GA) and local search strategy. Also proposes an efficient local search procedure that is applied to yield a better solution when ACO or GA obtains a solution. A final search is applied upon the termination of ACO and GA
110.	Amir Azaron, Reza Tavakkoli-Moghaddam	2006	Non-linear programming				The dynamic PERT network, representing as a network of queues, was transformed into an equivalent classical PERT network
111.	Luciano LessaLorenzoni et al.	2006		An evolutionary algorithm			An algorithm based on differential evolution algorithm was selected to serve as a solution procedure.
112.	Dieter Debels et al.	2006		SSGS	A new meta-heuristic(EM)		The procedure is a population-based evolutionary method that combines elements from scatter search, a generic population-based evolutionary search method, and from a recently introduced heuristic method for the optimization of unconstrained continuous functions based on an analogy with electromagnetism theory
113.	Hong Zhang et al.	2006		PSGS	Particle swarm optimization (PSO)		A PSO-based method including its corresponding framework is proposed for solving the RCPSB
114.	John-Paris Pantouvakis, Odysseus G. Manoliadis	2006		a heuristic method			A heuristic method is developed based on traditional CPM scheduling Calculations and leveling algorithms
115.	Guidong Zhu et al.	2006	A branch and cut				Based on the integer linear programming (ILP) formulation of the problem
116.	I-Tung Yang, Chi-Yi Chang	2005	Linear programming				Present a chance-constrained programming model, derive its deterministic equivalent, and solve the equivalent by classical linear programming techniques., Model verification is performed by Monte Carlo simulations
117.	Marek Mika et al.	2005		SSGS	Simulated annealing and TABU search		Applications of two local search meta-heuristics
118.	M.A. Al-Fawzan, Mohamed Haouari	2005		SSGS	TABU search algorithm		Develop a TABU search algorithm in order to generate an approximate set of efficient solutions
119.	KwanWoo Kim	2005		SSGS	Hybrid genetic	FLC	The proposed new approach is based on the design of genetic operators with fuzzy logic controller (FLC) through

					algorithm with fuzzy logic controller (FLC-HGA)		initializing the revised serial method which outperforms the non-preemptive scheduling with precedence and resources constraints
120.	Tamás Kis	2005	a branch-and-cut algorithm				Formalize the problem by means of a mixed integer-linear program, prove that feasible solution existence is NP-complete in the strong sense and propose a branch-and-cut algorithm for finding optimal solutions
121.	Sophie Demassey& Chiristian Artigues	2005	Lower bound, linear programming	A heuristic method			Propose a cooperation method between constraint programming and integer programming to compute lower bounds for the RCPSP.
122.	Krzysztof Fleszar, Khalil S. Hindi	2004		SSGS, variable neighborhood search(VNS)			In addition to the use of VNS to explore the solution space, the effectiveness of the scheme is due to progressively reducing the solution space by repeatedly improving both lower and upper bounds, as well as by discovering additional valid precedence to augment the existing set.
123.	Juite Wang	2004		SSGS	Genetic algorithm		Adapt a Branch-and-Bound algorithm for resource-constrained project scheduling by Bell and Park (1990) to the fuzzy case. And propose GA approach can obtain the robust schedule with acceptable performance
124.	I.E. Diakoulakis et al.	2004			Evolution Strategies (ES)		Under two discrete solution encodings; one works on vectors of priority values and the other is based on convex combinations of priority rules
125.	Reza Zamani	2004	Time window		SA		Procedure consists of a SA component and a time-windowing process. The SA component generates a base schedule and the time-windowing process improves the base. The combination of three factors contributes to the efficiency of the simulated annealing component
126.	ChristophMellentien	2004		A relaxation-based beam-search solution			Present a relaxation-based beam-search solution heuristic. Exploiting a duality relationship between temporal scheduling and min-cost network flow problems solves the relaxations.
127.	Vicente Valls & Francisco Ballestín	2004	SSGS, PSGS	Convex Search, Homogeneous Interval Algorithm (back ward, forward)	Scatter search		Procedure incorporates various strategies for generating and evolving a population of schedules. It is the result of combining four innovative basic procedures
128.	Philippe Baptiste & Sophie Demassey	2004		Tight LP bounds			14 more lower bounds are improved in an average CPU time of 284.6 seconds
129.	Mireille Palpant et al.	2004		SSGS	LSSPER		Present the Local Search with Sub-Problem Exact Resolution (LSSPER) method based on large neighborhood search for solving the problem
130.	A. LIM et al.	2004			A hybrid framework		This hybrid framework has a two-level structure. TS and GA heuristic searches were used in the high level components of algorithms. For the low level components, a CP-based iterative randomized method and a Minimal Critical Set-based method were used to resolve temporal and resource conflicts. The four combinations of these – Tabu_CP, Tabu_MCS, GA_CP, GA_MCS – were tested on two sets of real test data
131.	Christian Artigues et al.	2003		PSGS, a new			Show that such an algorithm is of great interest for robust rescheduling in a dynamic environment

				polynomial insertion algorithm			
132.	Vicente Valls et al.	2003		SSGS	A new meta heuristic algorithm CARA,		Non-standard implementation of fundamental concepts of TABU search without explicitly using memory structures embedded in a population-based framework, makes use of the TO representation of schedules
133.	J. Carlier& E. Néron	2003	Linear lower bounds (LLB)				First application that we present is a general linear programming scheme for computing a makespan lower bound. The second application consists in associating redundant resources with LLB
134.	DimitriGolenko-Ginzburg et al.	2003		RCGPS algorithm			Algorithm can be used for CAAN models which cover a broad spectrum of alternative stochastic networks
135.	Roland Heilmann	2003	Branch-and-bound				The solution method is a depth-first search based branch-and-bound procedure. It makes use of a branching strategy where the branching rule is selected dynamically. The solution approach is an integration approach where the modes and start times are determined simultaneously.
136.	Kwan Woo Kim et al.	2003		SSGS	Hybrid genetic algorithm (HGA) with fuzzy logic controller (FLC)	FLC	Based on the design of genetic operators with FLC and the initialization with the serial method, to find optimal or near-optimal initial solutions which has been shown superior for large-scale RCPSP
137.	M Kamrul Ahsan& De-Bi Tsao	2003		bi-criteria search strategy of a heuristic learning			Formulate a state-space representation of a heuristic search algorithm with a bi-criteria partial schedule selection technique. The heuristic solves problems in two phases. Also propose a variable weighting technique based on initial problem complexity measures.
138.	J Alcaraz et al.	2003			GA		Before the genetic algorithm itself is started, apply a preprocessing procedure over the project data, in order to reduce the search space.(to reduce the volume of the data and speed up the execution of their algorithm for this problem.)
139.	Chiu-Chi Wei et al.	2002		Enhanced TOC method			The enhanced TOC project scheduling technique determines the lower bound of the project length by using the combination of the existing heuristic algorithms, used to conduct the activity duration cut and establish project buffer, feeding buffer and resource buffer
140.	AmedeoCesta & Angelo Oddi	2002		A heuristic algorithm(ISES)			Use of an iterative sampling procedure which relies, on a constraint satisfaction problem solving (CSP) search procedure
141.	A Sprecher	2002		a new heuristic			The strategy combines elements of exact and heuristic solution procedures. It relies on decomposition of a problem into sub-problems, near optimal solution of the sub-problems, and concatenation of the sub-problem solutions. The algorithm significantly outperforms the truncated exact branch-and bound algorithm on larger instances.
142.	Mario Vanhouck et al.	2001	Branch-and-bound				Introduce a depth-first branch-and-bound algorithm which makes use of extra precedence relations to resolve resource conflicts and relies on a fast recursive search algorithm for the unconstrained weighted earliness–tardiness problem to compute lower bounds
143.	Birger Franck et al.	2001	Branch-and-bound	SSGS, heuristic procedures			Propose several truncated branch-and-bound techniques, priority-rule methods, and schedule-improvement procedures of types TABU search and genetic algorithm
144.	GunduzUlusoy et al.	2001			Genetic algorithm (GA)		Use a special crossover operator that can exploit the multi-component nature of the problem.
145.	Sönke	2001		SSGS	Genetic		Extending the genetic algorithm framework by local search

	Hartmann				Algorithm		concepts used two local search methods. One was designed to deal with the feasibility problem of the MRCPSP, while the other was used to improve the schedules found by the GA
146.	A. Kimms	2001	Tight Upper Bounds	Lagrangian relaxation			Derive tight upper bounds on the basis of a Lagrangian relaxation of the resource constraints And also use this approach as a basis for a heuristic
147.	J. Prashant Reddy et al.	2001			Genetic-algorithm		Describe Petri-net-aided software including genetic-algorithm-based search and heuristics
148.	Antonio Lova&PilarTormos	2001		SSGS, PSGS, New heuristics			Analyze the effect of the schedule generation schemes – serial or parallel and priority rules. Also New heuristics –based on priority rules with a two-phase approach
149.	Joanna Jozefowska et al.	2001		SSGS	A new simulated annealing algorithm		Two versions of the simulated annealing approach are discussed: SA without penalty function and SA with penalty function
150.	PilarTormos& Antonio Lova	2001		SSGS, PSGS, hybrid multi-pass method			Technique is a hybrid multi-pass method that combines random sampling procedures with a backward–forward also the algorithm includes as a determinant characteristic the alternative use of the serial and parallel schedule generation schemes in such a way that it benefits from the properties provided for both of them.
151.	Roland Heilmann	2001		Multi–pass priority–rule method			The heuristic is a multi–pass priority–rule method with back planning which is based on an integration approach and embedded in random sampling
152.	Gary Knotts et al.	2000		Eight agent-based algorithms			Develop and experimentally evaluate eight agent-based algorithms, algorithms differ in the priority rules used to control agent access to resources
153.	ChristophSchwindt & Norbert Trautmann	2000	Branch–and-bound algorithm				Solve to feasibility by a simple batching heuristic and the subsequent solution of the corresponding batch scheduling problem by a truncated version of the branch–and–bound algorithm within one minute
154.	Erik Demeulemeester et al.	2000	Branch–and-bound algorithm				Present a depth-first branch-and-bound procedure for the discrete time/resource trade-off problem in project networks (DTRTP)
155.	Ulrich Dorndrof et al.	2000	Time-oriented branch-and-bound				Describe a time-oriented branch and bound algorithm that uses constraint propagation techniques
156.	Arno Sprecher	2000	Branch-and-bound				The main purpose of this paper is direct focus to a branch-and-bound concept
157.	Tam P. W. M. & E. Palaneeswaran	1999		A new heuristic method			Note first outlines the suitability of ranked positional weight method (RPWM), a heuristic resource scheduling method, to construction project scheduling. It then focuses on a new heuristic technique, the enhanced positional weight (EPWM), which is an improved version of the RPWM. Some interesting comparisons between the results given by Primavera, Microsoft Project, RPWM, and EPWM are also presented
158.	Shue Li-Yen,RezaZamani	1999				An intelligent search method	Present an admissible heuristic search algorithm SLA, and an implementation method for solving the RCPSP, this algorithm is characterized by the complete heuristic learning process: state selection, heuristic learning, and search path review
159.	Paul R. Thomas &Said Salhi	1998			Tabu Search Approach(PSTSM)		Deal with a number of TABU search heuristic concepts in order to construct a method for this combinatorial problem, namely the PSTSM heuristic
160.	Abel A.Fernandez	1998			Alternative simulation		Introduces a multi-period stochasticing programming based model of the project scheduling problem

					algorithm		
161.	Aristide, Mingozzi et al.	1998	Branch and bounds, A new 0-1 linear programming formulation, a tree search algorithm	Relaxation heuristic method			Based on a new mathematical formulation which is used to derive 5 new lower bounds and also described a new tree search algorithm based on this exact formulation that uses the new bounds
162.	Dan Zhu &RemaPadman	1997				Artificial neural networks	Apply neural networks to induce the relationship between project parameters and heuristic performance to guide the selection under different project environments
163.	Rainer Kolisch& Andreas Drexl	1997		a new local search			Propose a new local search method that first tries to and a feasible solution and secondly performs a single-neighborhood search on the set of feasible mode assignments.
164.	Arno Sprecher et al.	1997	a new branch and bound algorithm				Present a new procedure which is a considerable generalization of the branch and-bound algorithm proposed by Demeulemeester and Herroelen
165.	Kedar S. Naphade et al.	1997			Two distinctly different problem space search procedures		Embed a fast base heuristic (for instance, a dispatching rule) within a search procedure, then showing comparable performance to the branch-and-bound algorithm.
166.	Moizuddin, Mohammed& Selim, S. Z.	1997			TS		The algorithm uses the priority space for generating neighbors. it also employed uses a short-term memory component. to optimize the TS parameters that developed are 3^k factorial design.
167.	Erik Demeulemeester, Willy S L Herroelen	1997	A new branch and bound algorithm				Describe a new depth-first branch-and-bound algorithm(GDH-PROCEDURE)
168.	Kum-Khiong, yang	1996		MINSLAK, CPR, FCFS	SA		A total of one scheduling and three heuristic dispatching rules that these planning rules are used to specify the priority of each activity in a project b ranking the precedence-feasible activities on an activity priority list.
169.	OyaIcmeli, S SelcukErengu c	1996	A branch and bound procedure				The bounds in the branch and bound procedure are computed by solving payment-scheduling problem that can be formulated as linear programs and by that are well solvable.
170.	F.Brian Talbot	1982	Integer program-ings	A heuristic solution			A two stages solution methodology is developed which builds upon idea presented earlier. Stage one defines the problem as a compact integer-programming problem, stage two searches for the optimal solution using an implicit enumeration scheme that systemically improves upon generated heuristic solutions.
171.	Jan Weglarz	1981	A priority analyses				The properties of optimal schedules are given for strictly, concave and convex activity models.
172.	Dale F Cooper	1976		PSGS, Tow classes of heuristic procedure			Assess the effects of the heuristic method, the project characteristics and the priority rules
173.	Arne Thesen	1976		A new heuristic method			Extend the fields of heuristic algorithms for RCPSP. a sub optimizing resource allocation algorithm is employed, A new hybrid heuristic urgency factor is introduced and finally a systematic approach to the evaluation of the such algorithm is presented
174.	E. W. Davis& G. E. Heidorn	1971		A dynamic programm			A dynamic programming approach that is a form of bounded enumeration. is presented to perform the shortest-path determination during construction of the a-network

				ing approach			
175.	A.Thomas Mason, Colin L Moodie	1971	A branch and bound procedure,	A heuristic method			Cost bounding procedures are augmented by dominance relationships presented as theorems. Initial feasible schedules are generated using a heuristic scheduling rule. Both heuristics rule and the branch and bound algorithm have been programmed for the computer
176.	Jerome D.Wiest	1967		A heuristic method			Describe a computer model capable of scheduling single or multiple projects within theirs constraints

In table 2 the approaches on RCPSP subject are categorized in different level. as seen most of the approaches are definite and discrete which is a big question that why researchers did not intend to work on other field.

Table 2: Approaches Categories

	Authors	Year	Approaches					Number of approaches	
			Det.	**Stochastic**				**Discrete**	**Integrated**
				Reactive	**Proactive**	**Stochastic**	**Fuzzy**		
1.	D.C. Paraskevopoulos et al.	2012	☑					☑	
2.	Chen Fang, Ling Wang	2012	☑					☑	
3.	Mohamed Haouari et al	2012	☑					☑	
4.	Ling Wangn, ChenFang	2012				☑		☑	
5.	Thomas S. Kyriakidis et al.	2012	☑					☑	
6.	Koorush Ziarati et al.	2011				☑		☑	
7.	Shu-Shun Liu, Chang-Jung Wang	2011	☑						☑
8.	FilipDeblaere et al.	2011			☑			☑	
9.	SiamakBaradaran et al.	2011	☑					☑	
10.	Mohammad Ranjbar et al.	2011	☑					☑	
11.	R. Čapek et al.	2011	☑					☑	
12.	MariemTrojet et al.	2011	☑					☑	
13.	Ling Wang, Chen Fang	2011	☑					☑	
14.	José Coelho, Mario Vanhoucke	2011	☑					☑	
15.	Ruey-Maw Chen	2011	☑					☑	
16.	Shanshan Wu et al.	2011	☑					☑	
17.	Mahdi Mobini et al.	2011	☑					☑	
18.	OumarKone et al.	2011	☑					☑	
19.	LucioBianco, MassimilianoCaramia	2011	☑					☑	
20.	Agustín Barrios et al.	2011	☑					☑	
21.	AnuragAgarwal et al.	2011	☑					☑	
22.	Francisco Ballestıín, Rosa Blanco	2011	☑					☑	
23.	FilipDeblaere et al.	2011		☑				☑	

24.	TarunBhaskar et al.	2011					☑	☑	
25.	GrzegorzWaligóra	2011	☑					☑	
26.	José Fernando Gonçalves et al.	2011	☑					☑	
27.	Vincent Van Peteghem,Mario Vanhoucke	2011	☑					☑	
28.	Reza Zamani	2011	☑					☑	
29.	Olivier Lambrechts et al.	2011			☑			☑	
30.	BehzadAshtiani et al.	2011				☑		☑	
31.	Francisco Ballestín et al.	2011	☑					☑	
32.	Jie Zhu et al.	2011	☑					☑	
33.	Mohammad Jaberi	2011	☑					☑	
34.	Hong Zhang,Feng Xing	2010					☑	☑	
35.	E. Klerides, E. Hadjiconstantinou	2010				☑		☑	
36.	Qi Hao et al.	2010	☑					☑	
37.	Svio B. Rodrigues, Denise S. Yamashita	2010	☑					☑	
38.	SondaElloumi , Philippe Fortemps	2010	☑					☑	
39.	AnisKooli et al.	2010	☑					☑	
40.	Jairo R. Montoya-Torres et al.	2010	☑					☑	
41.	SiamakBaradaran et al.	2010				☑		☑	
42.	Moslem Shahsavar et al.	2010	☑					☑	
43.	C.U. Fündeling, N. Trautmann	2010	☑					☑	
44.	Ruey-Maw Chen et al.	2010	☑					☑	
45.	Wang Chen et al.	2010	☑					☑	
46.	Vincent Van Peteghem , Mario Vanhoucke	2010	☑					☑	
47.	E. Klerides, E. Hadjiconstantinou	2010				☑		☑	
48.	Andrei Horbach	2010	☑					☑	
49.	Angela H. L. Chen & Chiuh-Cheng Chyu	2010	☑					☑	
50.	Wang Hong et al.	2010	☑					☑	
51.	Reza Zamani	2010	☑					☑	
52.	JiupingXu&Zhe Zhang	2010					☑	☑	
53.	Isabel Correia et al.	2010	☑					☑	
54.	Wang Xianggang& Huang Wei	2010					☑	☑	
55.	H. R. Yoosefzadeh et al.	2010	☑					☑	

56.	Angelo Oddi et al.	2010	☑					☑		
57.	Doreen Krüger&Armin Scholl	2010	☑					☑		
58.	YuryNikulin&Andreas Drexl	2010					☑	☑		
59.	Tyson R. Browning &Ali A. Yassine	2010				☑		☑		
60.	Fawaz S. Al-Anzi et al.	2010	☑					☑		
61.	M. Ranjbar& F. Kianfar	2010				☑		☑		
62.	N. Damak et al.	2009	☑					☑		
63.	PengWuliang, Wang Chengen	2009	☑					☑		
64.	Liang Yan et al.	2009				☑		☑		
65.	Po-Han Chen,Seyed Mohsen Shahandashti	2009	☑					☑		
66.	Po-Han Chen,HaijieWeng	2009	☑					☑		
67.	VikramTiwari et al.	2009	☑					☑		
68.	Jiaqiong Chen, Ronald G. Askin	2009	☑					☑		
69.	Mohammad Ranjbar et al.	2009	☑					☑		
70.	Antonio Lova et al.	2009	☑					☑		
71.	J.J.M. Mendes et al.	2009	☑					☑		
72.	Kuo-Ching Ying et al.	2009	☑					☑		
73.	Wu Yu et al.	2009	☑					☑		
74.	JörgHomberger	2011	☑					☑		
75.	C.C. Chyu&Z.J. Chen	2009	☑					☑		
76.	M. D. Mahdi Mobini et al.	2009	☑					☑		
77.	Christian Artigues& Cyril Briand	2009	☑					☑		
78.	Shu-Shun Liu,Chang-Jung Wang	2008	☑					☑		
79.	Nai-Hsin Pan et al.	2008	☑					☑		
80.	Stijn Van de Vonder et al.	2008		☑				☑		
81.	Francisco Ballestín et al.	2008	☑					☑		
82.	R. Alvarez-Valdes et al.	2008	☑					☑		
83.	J.F. Gonçalves et al.	2008	☑					☑		
84.	Hédi Chtourou & Mohamed Haouari	2008			☑			☑		
85.	Haitao Li, Keith Womer	2008	☑						**Supply chain configuration problem (SCCP) under resource constraints**	
86.	LuongDuc Long, ArioOhsato	2008					☑	☑		
87.	Mohammad Ranjbar	2008	☑					☑		
88.	Marek Mika et al.	2008	☑					☑		

89.	Mario Vanhoucke	2008	☑					☑	
90.	Shih-Tang Lo et al.	2008	☑					☑	
91.	Vicente Valls et al.	2008	☑					☑	
92.	L.-E. Drezet, J.-C. Billaut	2008	☑					☑	
93.	Mario Vanhoucke, Dieter Debels	2008	☑					☑	
94.	B. Jarboui et al.	2008	☑					☑	
95.	Sanjay Kumar Shukla et al.	2008					☑	☑	
96.	Olivier Lambrechts et al.	2008		☑	☑			☑	
97.	Olivier Liess&Philippe Michelon	2008	☑					☑	
98.	A. A. Lazarev& E. R. Gafarov	2008	☑					☑	
99.	MajidSabzehparvar& S. Mohammad Seyed-Hosseini	2008	☑					☑	
100.	Jean Damay et al.	2007	☑					☑	
101.	ShahramShadrokh, FereydoonKianfar	2007	☑					☑	
102.	Mohammad R. Ranjbar, FereydoonKianfar	2007	☑					☑	
103.	JirachaiBuddhakulsomsi, David S. Kim	2007			☑			☑	
104.	Stijn Van de Vonder et al.	2007		☑				☑	
105.	Jacques Carlier, Emmanuel Ne´ron	2007	☑					☑	
106.	M. Rabbani et al.	2007				☑			**RCPSP-TOC**
107.	VéroniqueBouffard&Jacques A. Ferland	2007	☑					☑	
108.	RinaAgarwal et al.	2007			☑			☑	
109.	Lin-Yu Tseng, Shih-Chieh Chen	2006	☑					☑	
110.	Amir Azaron, Reza Tavakkoli-Moghaddam	2006			☑			☑	
111.	Luciano LessaLorenzoni et al.	2006	☑						☑
112.	Dieter Debels et al.	2006	☑					☑	
113.	Hong Zhang et al.	2006	☑					☑	
114.	John-Paris Pantouvakis, Odysseus G. Manoliadis	2006	☑					☑	
115.	Guidong Zhu et al.	2006	☑					☑	
116.	I-Tung Yang, Chi-Yi Chang	2005			☑			☑	
117.	Marek Mika et al.	2005	☑					☑	
118.	M.A. Al-Fawzan, Mohamed Haouari	2005		☑				☑	
119.	KwanWoo Kim	2005					☑	☑	
120.	Tamás Kis	2005	☑					☑	

121.	Sophie Demassey&Chiristian Artigues	2005	☑					☑	
122.	Krzysztof Fleszar, Khalil S. Hindi	2004	☑					☑	
123.	Juite Wang	2004					☑	☑	
124.	I.E. Diakoulakis et al.	2004	☑					☑	
125.	Reza Zamani	2004	☑					☑	
126.	ChristophMellentien	2004	☑					☑	
127.	Vicente Valls & Francisco Ballestín	2004	☑					☑	
128.	Philippe Baptiste& Sophie Demassey	2004	☑					☑	
129.	Mireille Palpant et al.	2004	☑					☑	
130.	A. Lim et al.	2004			☑			☑	
131.	Christian Artigues et al.	2003		☑	☑			☑	
132.	Vicente Valls et al.	2003	☑					☑	
133.	J. Carlier, E. N_eron	2003	☑					☑	
134.	DimitriGolenko-Ginzburg et al.	2003				☑		☑	
135.	Roland Heilmann	2003	☑					☑	
136.	Kwan Woo Kim et al.	2003	☑					☑	
137.	M Kamrul Ahsan & De-Bi Tsao	2003	☑					☑	
138.	J Alcaraz et al.	2003	☑					☑	
139.	Chiu-Chi Wei et al.	2002				☑			**RCPSP-TOC**
140.	Amedeo Cesta& Angelo Oddi	2002	☑					☑	
141.	A Sprecher	2002				☑		☑	
142.	Mario Vanhoucke et al.	2001	☑					☑	
143.	Birger Franck et al.	2001	☑					☑	
144.	Gunduz Ulusoy et al.	2001	☑					☑	
145.	Sönke Hartmann	2001	☑					☑	
146.	A. Kimms	2001	☑					☑	
147.	J. Prashant Reddy et al.	2001	☑					☑	
148.	Antonio Lova & Pilar Tormos	2001	☑					☑	
149.	Joanna Jozefowska et al.	2001	☑					☑	
150.	Pilar Tormos & Antonio Lova	2001	☑					☑	
151.	Roland Heilmann	2001				☑		☑	
152.	Gary Knotts et al.	2000				☑		☑	
153.	Christoph Schwindt & Norbert Trautmann	2000		☑				☑	
154.	Erik Demeulemeester et al.	2000	☑					☑	

155.	Ulrich Dorndrof et al.	2000	☑					☑	
156.	Arno Sprecher	2000	☑					☑	
157.	Tam P. W. M. & E. Palaneeswaran	1999	☑					☑	
158.	Shue Li-Yen,RezaZamani	1999	☑					☑	
159.	Paul R. Thomas & Said Salhi	1998	☑					☑	
160.	Abel A.Fernandez	1998				☑		☑	
161.	Aristide, Mingozzi et al.	1998	☑					☑	
162.	Dan Zhu&RemaPadman	1997	☑					☑	
163.	Rainer Kolisch & Andreas Drexl	1997	☑					☑	
164.	Arno Sprecher et al.	1997	☑					☑	
165.	Kedar S. Naphade et al.	1997	☑					☑	
166.	Moizuddin, Mohammed;Selim, Shokri Z	1997	☑					☑	
167.	Erik Demeulemeester, Willy S L Herroelen	1997	☑					☑	
168.	Kum-Khiong, yang	1996				☑		☑	
169.	Oya Icmeli & S. Selcuk Erenguc	1996	☑					☑	
170.	F.Brian Talbot	1982	☑					☑	
171.	Jan Weglarz	1981	☑					☑	
172.	Dale F Cooper	1976	☑					☑	
173.	Arne Thesen	1976	☑					☑	
174.	Davis, Edward W;Heidorn, George E	1971	☑					☑	
175.	A.Thomas Mason, Colin L Moodie	1971	☑					☑	
176.	Jerome D.Wiest	1967	☑					☑	

6. Conclusion

Every day, better usage of the organizational resources such as machinery, human resource and materials are given more attentions. With existence of resource constraints, planning for achieving the goals of the contracts in projects, and at the top of them, time obligations, become more important. This paper described models and approaches in literature of project scheduling by considering resource constraints and the described models in literature that consist of more than 200 published articles in well known journals, are collected and provided in forms of a codified table. We tries to categorize models appropriately in this paper and surveys the proposed solutions for them by researches. By considering the increasing deployment of using planning and controlling project methods in organizations, factories and workshops such as powerhouse equipment construction projects and any kind of executive projects in various

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industries and totally, where ever there is usage of planning and controlling project, and by considering the diversity of organizations and factories, can identify the required model by considering the proposed criterions at beginning of this paper and researchers find the gaps in literature and try to fill them. We hope that the proposed solutions are reliable resources and references for gathering more information about different existence solutions in RCPSP literature.

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