Resolving Resource Conflicts in a Ship Repair Project

Khodakaram Salimifard, Gholamreza Jamali, and Sarah Behbahaninezhad

***Abstract*—Managing a project is a complex task. Traditional project management tools and models such as Graphical Evaluation and Review Technique (GERT), and Venture Evaluation and Review Technique (VERT) have not adequately incorporated a number of factors which can influence the resource assignment of projects. Consequently, it is essential to use powerful tools such as Petri nets in order to provide models which are closer to real-time ones. In this paper we use Resource Assignment Petri Net to model a ship repair project. This approach enables project managers to represent and evaluate different resource assignment strategies and interactions among activities and resources.**

***Index Terms*—Coloured petri nets, project control, RAPN.**

I. Introduction

Ship repair is a make-to-order operational system. Starting from the orders to the final delivery, the repair process is very complicated. Hence, the project scheduling including human, material, reusable resources and facilities is a very complex task. Poor resource assignment, keeps workers waiting for the prerequisite activities, causes fluctuation of workloads resulting in expensive overtime work, and may cause delay in delivery [1].

Before using computers for scheduling problems, project managers scheduled projects manually which was tedious and time consuming task and did not guarantee obtaining an optimal solution. The development of Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT) led to use of network diagrams for describing projects [2]. These techniques have been successfully applied in different projects for many years [3]-[8]. However, they severely suffer from unrealistic assumptions like the infinite availability of resources for each activity of the project [9]-[17]. Conventional management tools are incapable to resolve conflicts arising from scarcity of resources, activity execution priorities, and resource interdependencies.

During the last two decades, different planning and scheduling techniques such as branch and bound algorithm, zero-one programming, genetic algorithms, and Petri nets, have been proposed to resolve resource constraint issues in project management. To the best of our knowledge no algorithm has been proposed for the Resource Constrained Project Scheduling Problem (RCPSP) to combine the modeling power of Petri nets with the computation capability of Genetic Algorithm. To fill this gap, we propose in this paper a new scheduling method for the RCPSP.

The remainder of the paper is organized as follows. Section II devoted to literature review and related works. A brief introduction to Resource Assignment Petri Nets (RAPN) is covered in Section III. The case study is introduced in Section IV. The paper is concluded in Section V.

Manuscript received July 18, 2012; revised August 20, 2012.

Khodakaram Salimifard and Gholamreza Jamali are with Persian Gulf University, Bushehr, 75168 Iran (e-mail: salimifard@ pgu.ac.ir; gjamali@pgu.ac.ir).

II. Related Works

Resource management is an important issue in any project. It is concerned with the optimum assignment of resources to project activities. Resource scheduling and optimization are considered keys to successful execution of the project. Resources of a project have significant impacts on its completion and profitability. If required resources cannot be secured in time, the schedules of affected activities have to be rearranged [3]. This affects the project delivery date and makes the project more expensive and less profitable. Restrictions in projects are continuously changing. Furthermore, changing in environment may cause changes in project strategies, which makes it essential to use more flexible tools to manage and control a project [4].

Table I shows some researches on solving RCPSP. Based on the solution method, an RCPSP schedules a project with regard to resource availability.

TABLE I: Researches on Project Scheduling Problems

Reference	Year	Solution Method
Christofides et al. [6]	1087	Branch and Bound
Patterson [7]	1973	Zero-One Programming
Patterson & Roth [8]	1976	Zero-One Programming
Schirmer [9]	2000	X-Pass
Cervantes et al. [10]	2008	Genetic Algorithm
Montoya-Torres et al. [11]	2009	Genetic Algorithm
Chen et al. [4]	2008	Petri Nets
Thomas & Salhi [14]	1998	Tabu Search
Nonobe & Ibaraki [15]	2002	Tabu Search
Valls et al. [16]	2004	Simulated Annealing
Valls et al. [17]	2004	Simulated Annealing

Ship repair and/or construction can be seen as a project. Jae et al. [1] developed an integrated scheduling system called Daewoo Shipbuilding Scheduling (DAS). It solved difficulties in planning and scheduling of Daewoo's production process. The hierarchical architecture between systems, constraint directed graph search, spatial scheduling, dynamic assembly line scheduling, neural network based man-hours estimation and three-phased development strategy are key approaches that have contributed to the success of DAS project.

Jae and June [18] developed a regenerative expert system approach, called REGENESYS, which can modify the rules and program modules of standard expert system according to the changed specification. They also proposed and illustrated it with the scheduling expert systems for shipbuilding.

Kyoung et al. [19] developed a spatial scheduling expert system for shipbuilding. First, a methodology for spatial layout of polygonal objects within rectangular plates is developed, and then extended it to the methodology for spatial scheduling, including the time dimension. The methodology is applied to the scheduling of Daewoo shipbuilding to build a system called DAS-CURVE. It is successfully operational and its experimental performance is remarkable.

Zheng et al. [20] proposed a method based on game theory to handle the collaborative multidisciplinary decision making problems in the preliminary ship design process, and a 26,000 DWT oil ship design and analysis scenario was used as an example to illustrate the efficacy of the method.

Jing-Hua Li [21] developed ship multi-project scheduling system framework and MAS-based system model to schedule ship multiple projects with agility and adaptability. A negotiation mechanism for ship multi-project scheduling is proposed to coordinate these ship project agents. Modified contract net protocol was used to settle the critical resources assignment in ship multi-project scheduling. Also, an integrated scheduling optimization strategy was used to deal with the scheduling optimization problems in ship multi-project enterprise. At last, MPPSMA system which was developed on this basis verified the correctness of MAS-based negotiation mechanism for ship multi-project scheduling.

In this paper, the proposed model for ship repair project is based on Resource Assignment Petri Net which differs from other approaches by factoring in resource assignment specifically.

III. RAPN Constructs

RAPN approach has been introduced by three Taiwanese researchers, Yen-Liang Chen and colleagues [4]. The technique is applied to multiple projects in 2008. RAPN is a class of Petri nets and extends object composition Petri net (OCPN). RAPN can model all of the 13 temporal relationships, defined by Allen [22], between activities. Based on powerful characteristics of Petri nets, RAPN captures real-time factors such as concurrency and synchronization. It uses new places, transitions, attributes, and firing rules to model resource sharing and resource assignments. Furthermore, it can simulate various resource assignment strategies and compute the time needed to accomplish the involved projects [4]. Therefore, one can use analytical assessment tools which are unavailable in the traditional network representation of projects [23].

TABLE II: Resource Assignment Policies in RCPSP

Policy	Consumable Resources		Reusable Resources	
No sharing	Pat1		Pat2	
Different types of sharing	Rand.	Det.	Rand.	Det.
Sharing without temporal relation	Pat3	Pat4	Pat5	Pat6
Sharing with temporal relation	Pat7	Pat8	Pat9	Pat10

In RAPN, resources are divided into two categories: consumable (e.g. parts and materials) and reusable (e.g. human and devices) resources. A resource can be shared by multiple activities with random or deterministic assignment strategies and the activities sharing resources can be with or without temporal relationships. Table II shows the possible scenarios of resource assignments between any two activities [4]. The table illustrates 10 patterns, random (Rand.) and deterministic (Det.) strategies for resource assignment.

Also, before that, this approach was used in workflow management as a model, named as Resource Assignment Petri Net for Workflow Management (WF-RAPN). It extended traditional Petri Nets with resource assignments and case handling. It models workflow with the four dimensions of the process, resource, case and time at the same time [24].

In this research a ship repair project is mapped to RAPN model. This model represents how to assign resources to activities considering their complex relationships. It also captures the dynamic interactions between project activities.

IV. Case Study

Sadra [25] is the largest ship construction and repair company in Iran and in the Persian Gulf region. The company is operating under a make-to-order policy. A ship repair order is seen as a project; therefore the company project management division starts a project for each order.

TABLE III: Mehregan Ship Repair Data

Activity	Predecessor	PN Relation	Days	Resources
1	-	FS	1	DW
2	1	FS	1	DW
3	27	FS	1	DW
4	2	FS	2	C
5	2	FS	12	A, W
6	2	FS+2	14	A, W
7	2	FS+5	14	A, W
8	22, 19	FS+5	13	A, W
9	7	FS+1	2	A, W
10	3	FS	1	A, W
11	9	FS	1	A, W
12	10	FS	1	A, W
13	11	FS	3	E
14	2, 21	FS	3	PW
15	14	FS-1	9	PW
16	15	FS	1	T
17	16	SS	1	T
18	17	FS	2	T
19	23	FS	1	SZ, QC
20	-	FS	2	SZ, QC
21	2	FS	3	P
22	21	FS	9	SB
23	22	FS	7	SB
24	-	FS	4	SB, P, DW
25	23	FS	8	SB
26	23	FS	9	SB, P
27	23	FS-1	20	P
28	22	FS+2	6	P
29	25	FS+2	6	P
30	13	FS	3	P

Repairing a ship is a multi-task project involving many activities and resources. In case of multiple repair project sharing different limited resources, the project manager need to have a modeling tool to schedule different tasks of projects. In this paper, Mehregan ship repair project is studied and mapped into an RAPN model.

As it can be seen in Table III, Mehregan project consists of thirty activities. There are different FS (finish-to-start) precedence relationships between activities. Also, 10 different types of reusable resources are required.

For the sake of presentation simplicity, only reusable resources have been considered in this paper. The maximum capacity of 8 dock workers (DW), 2 cutters (C), 4 assemble workers (A), 4 welders (W), 2 electricians (E), 4 plumbers (PW), 4 turning workers (SB), 1 quality supervisor (QC), 1 scrambler (SZ), 4 sandblasters (SB) and 11 painters (P) are available.

If two activities are occurring at the same time from one coordinating transition, a delay place with zero time will be added to its representation to show concurrency and also we use this place to unify PN relations. For example, activity 6 starts 2 days after activity 2 is finished. Hence, a delay place for with 2 days delay will be used. Activity 15 starts 1 day before activity 14 is finished. In this case, we start both activities from one coordinating transition but to show the precedence relationship, we put a delay place with the time stamp equal to the duration of activity 14 minus 1 day.

On the other hand, in the project as a whole, the strategy of assigning resources to activities is deterministic because the required resources have been determined in advance. Activities 13 and 4 among the others just use one resource exclusively, and the rest are shared with other resources. Referring to Table II, activities 13 and 14 follow the pattern 2 and other ones follow patterns 6 and 10. These two patterns depend on the existence of temporal relations. For giving some examples in Mehregan project, we show allocation of resources in Fig. 1 and Fig. 2 based on pattern 6 and pattern 2, respectively.

In Fig. 1, dock workers are assigned to 3 activities. Activities 1 and 24 do not have temporal relation but start from the same coordinating transition and follow pattern 6. Furthermore, activity 2 uses dock workers after activities 1 and 24.

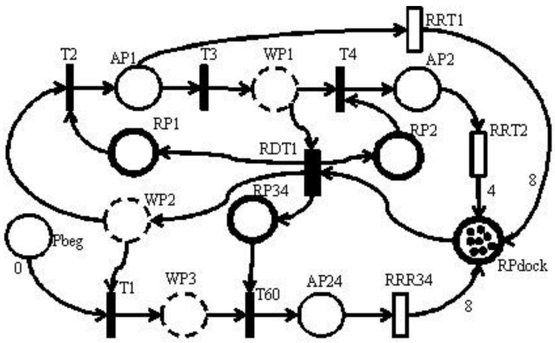

Fig. 1. Using pattern 6 (Pat6) to assign resources to an activity.

As shown in Fig. 2, an activity uses 2 SB (sandblaster) exclusively and follows pattern 2 according to Table 2. Obviously, activity 2 starts if required resources are available. It means, 2 tokens should be in place RP13 (representing required number of SB). Also, for the activity to start, it is required that one token should be in place WP13.

As soon as the execution of activity is finished, all the resource being utilized by activity will be released and the scheduling algorithm and the project proceeds.

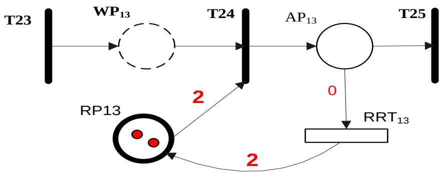

Fig. 2. Using Pat2 to assign electricians.

V. Conclusion

Resource assignment is one of crucial tasks of resource management in any project. In any ship repair project, many resources are required to be scheduled in order to complete the project on time. Scarcity of resources and conflicts between activities, among the others, make the resource assignment a very complex task.

In this paper, using a so-called RAPN modeling technique, we model the resource assignment of a ship repair project. It is shown that the proposed technique is capable to capture all requirements of resource allocation. It is also used to resolve the resource conflict problem enabling the project manager to schedule project activities. It is possible to embed real-time factors such as concurrency in this model.

References

[1] K. L. Jae, J. L. Kyoung, K. P. Hung, S. H. June, and S. L. Jung, "Developing Scheduling Systems for Daewoo Shipbuilding: DAS Project," *European Journal of Operational Research*, vol. 97, no. 2, pp. 380-395, 1997.

[2] A. S. Kheirkhah and M. H. Kargarfard, *Characteristics and Methods of Solving Resource Constrained Multi Project Scheduling Problem*, The Forth International Conference of Project Managemen, Tehran, Iran, 2008.

[3] A. Roumboutsos, N. Litinas, and E. Tobaloglou, "Management by projects in maritime organisations," *Journal of Marine Science and Application*, vol. 4, no. 3, pp. 24-29.

[4] Y. L. Chen, P. Y. Hsu, and Y. B. Chang, "A Petri Net Approach to Support Resource Assignment in Project Management," *IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans*, vol. 38. no. 3, 2008.

[5] A. Momeni and A. S. Kheirkhah, *A Model for Preventing Projects Delays by Dynamic Decision Making Approach*, The Second International Conference of Project Management, Tehran, Iran, 2005.

[6] N. Christofides, R. Alvarez-Valdes, and J. M. Tamarit, "Project Scheduling with Resource Constraints: A Branch and Bound," *European Journal of Operational Research*, vol. 29. pp. 262-273, 1987.

[7] J. H. Patterson, "Alternate Methods of Project Scheduling with Limited Resources," *Naval Research Logistics*, vol. 20. pp. 767-784, 1973.

[8] J. H. Patterson and G. W. Roth, "Scheduling a Project under Multiple Resource Constraints: A Zero-One Programming Approach," *AIIE Transactions*, vol. 8, pp. 449-455, 1976.

[9] A. Schirmer, "Case-based reasoning and improved adaptive search for project scheduling," *Naval Research Logistics*, vol. 47, pp. 201-222, 2000.

[10] M. Cervantes, A. Lova, P. Tormos, and F. Barber, *A Dynamic Population Steady-State Genetic Algorithm for the Resource-Constrained Project Scheduling Problem*, N. T. Nguyen et al. (Eds.): IEA/AIE, LNAI 5027, Springer-Verlag, pp. 611-620, 2008.

[11] J. Montoya-Torres, E. Gutierrez-Franco, and C. Pirachićan-Mayorga, "Project Scheduling with limited Resources Using a Genetic Algorithm," *International Journal of Project Management*, 2009.

[12] S. Hartmann, "Project Scheduling with Multiple Modes: A Genetic Algorithm," *Annals of Operations Research*, vol. 102, pp. 111-135, 2001.

[13] H. P. Kao, B. Hsieh, and Y. Yeh, "A Petri-Net Based Approach for Scheduling and Rescheduling Resource-Constrained Multiple Projects," *Journal of the Chinese Institute of Industrial Engineers*, vol. 23, no. 6, pp. 468-477, 2006.

[14] P. R. Thomas and S. Salhi, "A Tabu search approach for the Resource Constrained Project Scheduling Problem," *Journal of Heuristics*, vol. 4, pp. 123-139, 1998.

[15] K. Nonobe and T. Ibaraki, "Formulation and Tabu Search Algorithm for the Resource Constrained Project Scheduling Problem," in *C. C. Ribeiro and P. Hansen (Eds), Essays and Surveys in Metaheuristics*, pp. 557-588, 2002.

[16] V. Valls, F. Ballestin, and M. S. Quintanilla, "Justification and RCPSP: A technique that pays," *European Journal of Operational Research*, 2004.

[17] V. Valls, M. S. Quintanilla, and F. Ballestin, "Resource Constrained Project Scheduling: A Critical Activity Reordering Heuristic," *European Journal of Operational Research*, 2004.

[18] K. L. Jae and S. H. June, "A Generative Expert System Approach for the Maintenance of Expert Systems," *Expert Systems with Applications*, vol. 14, pp. 313-321, 1998.

[19] J. L. Kyoung, K. L. Jae, and Y. C. Soo, "A Spatial Scheduling System and its Application to Shipbuilding: DAS-CURVE," *Expert Systems with Applications*, vol. 10, no.3/4, pp. 311-324, 1996.

[20] X. L. Zheng, Y. Lin, and Z. S. Ji, "Collaborative multidisciplinary decision making based on game theory in ship preliminary design," *Operational Research*, vol. 4, no. 3, pp.399-409.

[21] J. H. Li, "MAS-based negotiation mechanism for ship multi-project scheduling," *Machine Learning and Cybernetics International Conference*, vol. 3, pp. 1388–1392, 2009.

[22] J. F. Allen, "Maintaining Knowledge about Temporal Intervals," *Communication ACM*, vol. 26, no. 11, pp. 832-843, 1983.

[23] J. Kim, A. A. Desrochers, and A. Sanderson, "Task Planning and Project Management Using Petri Nets," *IEEE Xplore*, 1995.

[24] P. Y. Hsu, and Y. Li. Chen, and Y. B. Chang, "A Formal Dimensional Petri Net Approach for Workflow Management," *Lecture Notes in Computer Science*, vol. 3882, pp. 617-627, 2006.

[25] Sadra. [Online]. Available: http://www.sadra.ir/default.aspx

K. Salimifard was born in Borazjan, Iran, in 1962. He received his B.Sc. in industrial management from Shiraz University Iran in 1983. He holds a master degree in industrial management from Tarbiat Modares University, Iran. He received his Ph.D. in Management Science from Lancaster University UK in 2002. He was with the Lancaster University management science department from 1999 to 2002 teaching operational research courses. Dr. Salimifard is an assistant professor of Management Science at the Industrial Management Department at the Persian Gulf University, Bushehr Iran. Currently he is the head of the department. His main research interests include modeling and optimization of project scheduling and business processes using Petri nets and meta-heuristics (GA, TS, SA, ACO). Also, he is interested in the applications of Coloured Petri nets (CPN), discrete event simulation, and mathematical programming. Dr. Salimifard has published papers in peer reviewed journals and international conferences. He is a member of Iranian Association for Operational Research, Iranian Project Management Institute, and UK OR society.

G. Jamali is an Assistant Professor at Persian Gulf University, Bushehr, Iran. Dr. Jamali holds a bachelor and a master's degree in Industrial Management from Shiraz University. He completed his Ph.D. degree in production and operation management at Tehran University. His area of research interest include supply chain management, workforce scheduling, supply chain, project management, business process reengineering, quality management, enterprise resourse planning and knowledge management. Dr. Jamali has published many papers in national and international journals and conferences. He has worked as a consultant in many organizations.

S. Behbahaninezhad was born in Shiraz, Iran, in 1986. She received her B.Sc. in industrial management from Persian Gulf University Iran in 2007. She received her M.Sc. in industrial management from Persian Gulf University, Iran in 2010. Currently, she works for Pasargad Bank. Her main research interests include modeling and optimization of project scheduling, genetic algorithm, and financial optimization.