A New Heuristic for Scheduling Optimization of Non-Repetitive Construction Projects under Constrained Resources

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ABSTRACT- In Sudan, the clients, contractors and consultants (stakeholders) suffer from the elongation of project completion time, especially in the case of limited resources. This problem results in the conflict among them, and hence leads to project delay that consequently influences the overall project cost. To solve this problem, data from ten construction projects executed in Khartoum state and other towns was collected, simulated and analyzed. Primavera software program was used as a simulator tool and sixteen selected heuristics were applied to the ten projects. Statistical and operational research tools combined with the existing heuristics, while considering best common practices in construction industry, were used. Lindo software, as a decision making tool, is then used to find the optimum solution, i.e., finding the minimum time to complete the project under limited resources. The results were then evaluated and, hence, concluded that the optimum solution of the extra needed time at its minimum possible rate (to complete the project under limited resources) was achieved as a result of implementing the heuristic of "minimum late start time". This new "selected" heuristic optimizes the scheduling time of non-repetitive projects while considering the availability of limited resources.

Keywords: *Non-repetitive projects; Limited resources; scheduling optimization; Heuristic.*

المستخلص – ظلت اطراف مثلث التشييد (المالك والمقاول والاستشاري) في السودان يعانون وباستمرار من مشكلة الاطالة في زمن اكمال المشروع و بصورة خاصه في حالة الموارد المحدودة او المقيدة مما ينتج عنه اختلاف بين الاطراف الثلاثة ومن ثم يقود هذا الي التاخيرفي زمن اكمال المشروع مما يودي بالضرورة الي الارتفاع تكلفتة الكلية في نهاية الامر. لحل هذه المشكلة فانه تم جمع ومحاكاة وتحليل معلومات من عشرة مشاريع انشائية نفذت في ولاية الخرطوم وبعض المدن الاخري. تم استخدام برنامج البرايمافيرا (Primavera) كاداة للمحاكاة ثم طبقت ستة عشرة فرضية (Heuristic) تم اختيارها علي المشاريع العشرة. تم استخدام وسائل احصائية و وسائل بحوث العمليات مع الفرضيات (Heuristics) مع الوضع في الاعتبار ان افضل التطبيقات السائدة في صناعة التشييد قد تم استخدامها. من ثم تم استخدام برنامج الكمبيوتر(Lindo كاداة لصنع القرار)للوصول للحل الامثل المطلوب وهو الحصول علي اقل زمن ممكن لاكمال المشروع في حالة الموارد المقيدة. تم تحليل النتائج والتي خلصت الي ان الحل الامثل للزمن الاضافي المطلوب في معدله الادني لاكمال المشروع (في حالة الموارد المقيدة) قد تم تحقيقه كنتيجة لتطبيق فرضية (Heuristic) اقل زمن بدء متاخر (Minimum late start time). ان هذه الفرضية الجديده المختارة تمثل جدولة زمنية مثلي لمشاريع غير متكرره باعتبار حالة الموارد المقيدة.

INTRODUCTION

Scheduling problem of simple and complex projects have been proposed, implemented, and evaluated since World War II, and till now [1]. Optimization of project scheduling through time control is considered as the most important factor in project management. Many studies were carried out and many models and software packages were developed. Heuristic methods are used to optimize scheduling of construction projects. They analyze activities and schedule only one at a time [1]. Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT) were the most popular network techniques for scheduling. Nevertheless, the two types of methods do not consider the limited resources availability in many circumstances. However both methods are considered as feasible procedures for producing non-feasible schedule [1].On the other hand, resource leveling is used to reduce the sharp variations (i.e., tackling the problem of infeasibility) in the resource demand, although, it cannot handle the issue of minimizing project duration. Since, it is used when there are enough resources, the leveling process is accomplished by shifting only the non-critical activities within their floats[2], [3].

In *project scheduling problems*, a single project consists of a set of tasks, or activities that have precedence relationships. The tasks also have estimated durations and may include various other measures such as cost.However, the most common objective in the project scheduling problem is the minimization of the time to complete the entire project. In *multi-modal project scheduling problems*, each task may be executed in more than one mode, and each mode may have different resource requirements and more than one project may be scheduled, simultaneously. In many scheduling problems an implicit assumption mode is that sufficient resources are available and only the technological constraints (precedence relationships) are used for setting schedules. However, in most cases, resources constraints have not to be ignored, i.e. manpower, raw materials and equipment.

Advancements in computers' capabilities in the 1990s, eventually, made it possible to overcome many deficiencies in the scheduling techniques being used in earlier projects. Development of a wide variety of affordable project management software packages, i.e., Microsoft and Primavera Project Planner, make problems handling easier. These packages allow the projects' teams to plan and control their projects in a completely interactive mode, however, these programs cannot guarantee a successful project plan [4]. The base of application is the usage of a specific heuristic model (rule) to set the activities sequencing. Verhines (1963) [5] , advocated general use of the "minimum late-finish-time" (LFT) priority rule, apparently on the basis of its ability to produce shorter schedules than other rules tested for a few selected problems. Brand, Meyer and Patterson et al. (1964-1973) reported nine heuristic rules for constrained resource project scheduling in a chronological order and indicated the type of problems examined [4].They found that the sequencing rule they used is effective as a duration measure (time slippage) for single-and-multi-projects [6]. In his "heuristic model for scheduling large projects with limited resources", Davis (1969) developed a study that compared the performance of the heuristics with optimal solutions founded by a bounded enumeration method; then Davis and Heidorm (1971) programmed the study for computation [7]. Davis and Patterson, (1975) compared the performance of eight standard heuristics on a set of single-mode resource-constrained project with the optimal solutions of Davis and Heidorn and they found that the Min. slack (MINSLK) rule produced an optimal schedule span, most of the times. Continuously comparing the other rules (heuristics) for a single-project, multi-resource scheduling, researchers found that either the late finish time (LFT) or late start time (LST) rules are the most effective ones. Thus the three rules, MINSLK/LFT/and LST, taken as a group, produce better results than the others [8]. Generally, a proposed heuristic algorithm may rank possible heuristics' combinations every time and simultaneously schedules all activities in a selected combination. They compare the performance of the created heuristics with optimal solutions (Davis and Patterson, 1973).Davis (1975) and Cooper (1976) et al [9].surveyed a range of heuristics from simple priority rules to very complex dispatch rules. Patterson (1976) confirmed previous studies regarding LFT and LST as the most effective rules and hence their results supported the previous findings of Stinson et al. (1976, 1978) [10] who developed a branch and bound (skip tracking) procedure to solve the multiple constrained resource project scheduling problem[11]. Patterson (1984) presented an overview of optimal solution methods for project scheduling. He noted that the linear programming can be used only for specific instances or small problems [12]. Lawrence et al. (1993) described an approach that attempted to minimize weighted tardiness by using a combination of project activities and resource-related metrics [13].Boctors (1990) presented experiments with multiple heuristics that clearly showed the benefits of combining the best of the single-heuristic methods [14]. Hildum (1994) made the distinction between single- and multiple-heuristic approaches while emphasizing the importance of maintaining multiple scheduling perspectives [14]. Merkle (2002) presented the first application of ant systems to the resource constrained project scheduling problem. Agarwal (2003, 2005) applied the Aug neuralnetwork (Aug NN) approach for parallel schedule as a special case of resources scheduling problem [4]. Guldemond and Hurink et al. (2008) proposed a new approach of two stages heuristic for Time-Constrained Project Scheduling Problem (TCPSP)[15]. Mendesaand GonçAlves (2009) presented a new genetic algorithm for finding cost-effective solutions for the Resource constrained project scheduling problem (RCPSP) [4]. SiamakBaradaran et al. (2010) presented a methaheuristic algorithm for resource-constrained project scheduling problem (RCPSP) in PERT networks to minimize the regular criterion namely project's makespan [16]. Ballestin and Blanco (2011) presented a study deal with multi-objective optimization in resource-constrained project scheduling problems (MORCPSPs) [17]. Guoqiang Li et al. (2012)presented a study for development and investigation of efficient artificial bee colony algorithm for numerical function optimization.They noted that it is more effective than genetic algorithm (GA) [18].Ultimately, many other alternative methods for project scheduling problems with limited multi-modes resources associated with different durations were developed by many scholars, i.e., Carruthers and Battersby (1966-1976); Davis and Heidorn (1971); Patterson (1973, 1984), etc [1],[4].

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PROBLEM STATEMENT

In Sudan, stakeholders of the construction industry are generally suffered from prolonged project execution time. This is specifically true in the case of limited resources that, ultimately, lead to overrun of the total project cost.

OBJECTIVES OF THE RESEARCH

The objectives of this research are to plan and control none repetitive project time through scheduling, aiming at time optimization, while considering constrained resources; and to develop a heuristic based on a preset criteria, while considering the best practices of the Sudanese construction industry, to optimize scheduling of none repetitive projects.

METHODOLOGY

To solve the problem of project time completion, specifically under limited resources, we followed heuristics application approach. We built up the actual studying models from data of ten non-repetitive projects. Data was collected, simulated and analyzed. Primavera program is used as a simulator tool. Sixteen selected heuristics are then applied to the ten projects. Statistical and operation research tools combined with existing heuristics and the best common practices in construction industry were used. The analysis process is culminated by applying Lindo to reach the optimum solution i.e. minimum time to complete the project under resource limitation.

The ultimate outcome of the research is to develop a new heuristic model for none repetitive projects applicable within the local Sudanese construction environment.

SCOPE OF WORK

Ten Ten, none repetitive projects executed in Khartoum State and other major towns in Sudan (Marwi, Karema, Eldaba, Dongla), were selected, as an integrated case study. Each project is described in details (i.e. number of activities, resources, durations, target time of completion, expected cost, etc.).

STUDY AND RESULTS

In this study we applied sixteen heuristics to the ten selected projects (case study) as the actual studying models using primavera project planner program (P_3) as a simulator tool which led to the simulation product models.

Heuristics Selection

Two groups of heuristics were applied:

a) Single Heuristics:

In this case the highest priority will be given to the following heuristics when two activities or more compete for the same resources, and can be scheduled at the same time:

Heuristic No. 1: Give priority to the activities having the minimum total float (M.T.F.)

Heuristic No. 2: Give priority to the activities having minimum late start time (M.L.S.T.)

Heuristic No. 13: Give priority to the activities having minimum late finish time (M.L.F.T.)

b) Combined Heuristic

In this group dual and triple heuristics were applied. First heuristic is used when more than one activity compete to the same resources and can be scheduled at the same time, while the second one is used as a tiebreaker and so forth the third one (second tiebreaker) because the (P_3) schedules the activities having the highest priority codes before the ones with the lower priority codes.

Dual Heuristics

Heuristic No. 3: Give the priority to M.L.S.T. whiles the second one (tiebreaker) will be given to M.T.F.

Heuristic No. 4: Give the priority to min early start time M.E.S.T. and the second one to M.T.F.

Heuristic No. 5: Give the priority to maximum (greatest) resource demand. (M.R.D) and second one to the minimum duration (M D).

Heuristic No. 6: Give the priority to the maximum resource demand (M.R.D.) and the second one to M.T.F.

Heuristic No. 7: Give the priority to the minimum activity usage (M.A.U) and second one to M.T.F.

Heuristic No. 14: Give the priority to M.L.F.T. and second one to M.T.F.

Triple Combined Heuristics

Heuristic No. 8: Give the priority to M.L.S., second priority (tiebreaker) M.T.F and 3rd one (second tiebreaker) to M.D.

Heuristic No. 9: Give the priority to M.E.F., second one to M.T.F., and the third one to the min. duration (M.D).

Heuristic No. 10: Give the priority to M.R.D., second one to M.D. and the third one to M.T.F.

Heuristic No. 11: Give the priority to M.A.U., second one to M.D., and the third one to M.T.F.

Heuristic No. 12: Give the priority to M.A.U., second one to M.T.F., and the third one to M.D.

Heuristic No. 15: Give the priority to M.L.F.T. and the second one to M.T.F. and the third one to (M.D).

Heuristic No. 16: Give the priority to M.E.S.T., second one to M.T.F., and finally the third one to M.D.

IMPLEMENTATION STEPS

The projects were entered to the primavera with all their activities abiding by their precedence order, and durations which obtained from contractors who executed the projects. Then, every project time is adjusted, i.e. subjected to specific calendar; also the projects resources are assigned as obtained from the contractors; taking into consideration that all resources were assigned to activities

Table 1: Projects initially planned finishing dates

Project name	Project finishing dates	Project name	Project finishing dates
Geological research center	4/10/2002	Tuti suspended bridge	30/6/2009
Marwi- Karema bridge	20/2/2009	Al- Fateh tower	26/3/2006
Eldaba- Dongla road	30/6/2008	Khrt.College for Medical Sciences	4/11/2004
Marwi Airport	20/2/2009	M. Sciences School (U.of K.)	9/10/2001
National telecommunication tower	16/10/2008	Marwi Dam	25/11/2007

Table 2: New planned finishing dates with time constraints

Project name	Project finishing dates	Project name	Project finishing dates
Geological research center	4/9/2002	Tuti suspended bridge	5/7/2008
Marwi- Karema bridge	3/1/2008	Al- Fateh tower	10/8/2005
Eldaba- Dongla road	17/5/2008	Khart, College for Medical Sciences	19/3/2003
Marwi Airport	20/2/2008	M.Sciences School (U.of K.)	18/9/2001
National telecommunication tower	8/6/2008	Marwi Dam	10/9/2007

Table 3: New simulated projects finishing dates without time constraints

Project name	Finishing date (phase 1)	Finishing date (phase 2)	Project name	Finishing date (phase 1)	Finishing date (phase 2)
Geological center	2/8/2003	14/2/2003	Tuti bridge	7/6/2010	19/11/2009
Marwi- Karema bridge	7/6/2011	3/9/2012	Al- Fateh tower	27/7/2008	1/9/2008
Eldaba- Dongla road	9/9/2014	19/11/2014	Khartoum College	15/7/2003	2/9/2003
Marwi Airport	28/12/2010	29/3/2011	M. Sciences School	6/11/2002	30/4/2002
National telecom tower	6/2/2012	4/6/2011	Marwi Dam	3/10/2014	22/7/2014

with their real quantities and cost. Bearing in mind that the initially planned finishing times (assumed) for all projects are already known as shown in Table 1.

Projects Scheduling

After all projects were entered to the simulator with their activities and resources, then scheduling process was done with time constraints choice, so the initially (early) planned project finishing dates were determined.

Projects leveling

To treat the over allocation of resources which is evident that after the scheduling step was done, we undertook a leveling step with time constraints choice and minimum late start plus minimum total float heuristic as the default one in primavera program prioritization box (Primavera manual 2010) . Consequently, the previous initially planned finishing dates are changed to new planned finishing dates as shown in Table 2.

Heuristics Application to Projects: The available heuristics were applied to all projects sequentially in two phases: first, we applied the heuristics from first heuristic to last one and vice versa; the second phase with forward and without time constraints choice. So, new simulated projects dates (maximum delay dates) of two phases were found as shown in Table 3.

So, the initially planned finishing dates (Table 1) were compared with the new planned finishing dates (Table 2) which produced new simulated finishing dates (Table 3). We found, after resources over allocation treatment, that the new planned finishing dates were earlier than the initially planned ones when the projects were subjected to limited resources, while the new simulated finishing dates were delayed beyond the initially planned ones (Appendix I). So, this indicates that the simulated projects produced schedules with higher average times while achieving lower tardiness costs than did the initially planned ones.

During the application of the two phases, each time we selected the specific heuristic from the prioritization box, leveling step is done. So, values of time increase (Δtp) due to the application of the heuristics are shown in Appendix "II" (first phase) and Appendix "III" (second phase). Where Appendix "IV" represents the average values of the "Δtp(s)" of the two phases, while Appendix "V" calculates their percentage values that were used as coefficients of the "Xi(s)" variables. We applied the heuristics in two phases to give the heuristics same chances of performance because when we were trying to treat the over allocation of resources through simulation procedures (rescheduling the activities), it was clear that there was no progress in over allocation treatment, so we added resources gradually in min rates in first phase and at their max ones in the second phase.

Using linear programming technique:

As a result, of heuristics re-visiting, we have (16) equations by (16) unknowns, and by using linear programming techniques it was possible to reach a solution through solving the optimization matrix which contained (160) elements, as shown in Figure 1. The formulation of the problem is as follow:

The objective function will be: Minimize

Z = X1+X2+…+X16

Subject to:

$$\Delta_{1,1} X_1 + \Delta_{1,2} X_1 + \Delta_{1,3} X_1 + \ldots\ldots\ldots + \Delta_{1,10} X_1 \le 0 \quad \ldots (1)$$

$$\Delta_{2,1} X_2 + \Delta_{2,2} X_2 + \Delta_{2,3} X_2 + \ldots\ldots\ldots + \Delta_{2,10} X_2 \le 0 \quad \ldots (2)$$

And so on till to:

$$\Delta_{16,1} X_{10} + \Delta_{16,2} X_{10} + \Delta_{16,3} X_{10} + \ldots\ldots + \Delta_{16,10} X_{16} \le 0 \quad \ldots (16)$$

$X_1, X_2, x_3, \ldots\ldots X_{16} \ge 0$

Optimization Matrix

The objective function (Z) is:
Minimize : Z = X1+X2+X3+X4+X5+X6+X7+X8+X9+X10+X11+X12+X13+X14+X15+X16
Subjected to:
0.14X1+0.65X1+1.39X1+2.12X1+0.55X1+0.26X1+0.48X1+0.13X1+2.75X1+1.521 ≤ 0
0.31X2+0.64X2+1.54X2+2.21X2+0.59X2+0.25X2+0.49X2+0.1X2+2.84X2+1.42X2 ≤ 0
0.23X3+0.55X3+1.25X3+2.28X3+0.67X3+0.2X3+0.47X3+0.11X3+2.9X3+1.54X3 ≤0
0.32X4+0.62X4+1.11X4+2.17X4+0.61X4+0.14X1+0.25X4+0.09X4+2.97X4+1.54X4 ≤ 0
0.26X5+0.62X5+1.01X5+1.95X5+0.5X5+0.26X5+0.06X5+0.07X5+3.22X5+1.16X5 ≤ 0
0.18X6+0.5X6+1.0X6+1.37X6+0.56X6+0.12X6+0.06X6+0.09X6+3.14X6+0.72X6 ≤ 0
0.22X7+0.53X7+0.91X7+1.21X7+0.58X7+0.06X7+0.05X7+0.08X7+3.35X7+0.89X7 ≤ 0
0.14X8+0.59X8+0.81X8+1.08X8+0.59X8+0.06X8+0.06X8+0.09X8+3.48X8+0.53X8 ≤ 0
0.11X9+0.59X9+0.8X9+1.1X9+0.59X9+0.07X9+0.06X9+0.08X9+1.42X9+0.9X9 ≤ 0
0.33X10+0.56X10+0.96X10+1.16X10+0.39X10+0.14X10+0.07X10+0.1X10+1.56X10+0.8X10≤ 0
0.05X11+0.58X11+1.03X11+1.15X11+0.49X11+0.25X11+0.08X11+0.09X11+1.54X11+1.12X≤ 0
0.18X12+0.66X12+1.26X12+1.37X12+0.48X12+0.14X12+0.22X12+0.09X12+1.54X12+1.41X≤ 0
0.14X13+0.7X13+1.51X13+2.55X13+0.55X13+0.21X13+0.36X13+0.16X13+1.5X13+1.41X13 ≤ 0
0.11X14+0.68X14+1.47X14+2.3X14+0.47X14+0.14X14+0.36X14+0.2X14+1.4X14+1.43X14 ≤ 0
0.1X15+0.83X15+1.44X15+2.24X15+0.5X15+0.22X15+0.37X15+0.21X15+0.15X15+1.47X15 ≤ 0
0.14X16+0.79X16+0.56X16+1.69X16+0.54X16+0.14X16+0.5X16+0.21X16+0.2X16+1.44X16 ≤ 0
X1…..X16 ≥ 0
END

Figure 1: Optimization Matrix by using linear programming techniques

Table 4: Matrix solution by Lindo Program for Xi values (Heuristics organized according to the adopted criteria)

No.	Variable	Value	Heuristic name	No.	Variable	Value	Heuristic name
1	X_2	0.096246	M.L.S.	9	X_6	0.129199	M.R.D. + M.T.F.
2	X_3	0.098039	M.L.S.+ M.T.F.	10	X_{15}	0.132802	M.L.F.+ M.T.F.+ M.D.
3	X_1	0.100100	M.T.F.	11	X_8	0.134590	M.L.S.+ M.T.F.+ M.D.
4	X_4	0.101833	M.E.S.+ M.T.F.	12	X_{12}	0.136054	M.A.U. + M.T.F. + M.D.
5	X_5	0.108814	M.R.D. + M.D.	13	X_{11}	0.156740	M.A.U. + M.D. + M.T.F.
6	X_{13}	0.110011	M.L.F.	14	X_{16}	0.161031	M.E.S. + M.T.F.+ M.D.
7	X_{14}	0.116822	M.L.F.+ M.T.F.	15	X_{10}	0.164745	M.R.D. + M.D. + M.T.F.
8	X_7	0.126904	M.A.U. + M.T.F.	16	X_9	0.174825	M.E.F.. + M.T.F.+ M.D.

Lindo is, then, applied to solve the matrix, so the results are shown in table "4", in terms of the "X_i" values and generated heuristics.

The solution of the matrix explained the final results of the unknowns Xi, i = 1-16 i.e. from X_1 to X_{16} (which known already as simulation products models-SPM) as follow:

X_1: represents the optimum solution of increasing the time needed due to the application of H_1

X_2: represents the optimum solution of increasing the time needed due to the application of $H_{2;}$

and so on:

X_{16}: represents the optimum solution of increasing the time needed due to the application of $H_{16.}$

CONCLUSION

To solve the problem of project time completion, specifically under limited resources, we followed heuristics application approach. We built up the actual studying models from data of ten non-repetitive. Data was collected, simulated and analyzed. Primavera program is used as a simulator tool. Sixteen selected heuristics are then applied to the ten projects. Statistical and operation research tools combined with existing heuristics and the best common practices in construction industry were used. The analysis process is culminated by applying Lindo to reach the optimum solution i.e. minimum time to complete the project under resource limitation. The results were then evaluated and the following outcomes are obtained:

- The optimum solution of extra needed time at its minimum possible rate to complete the project under limited resources is achieved as a result of applying the heuristic of "minimum late start time" (single heuristic).
- The second optimum solution is achieved as a result of applying the heuristic of "minimum late start time plus minimum total float time" (dual heuristic).
- The third one is achieved as a result of applying the heuristic of "minimum total float time" (single heuristic).
- The other heuristics are organized as a result of specific criteria in a descending order according to their affect in the optimum solution.

So, a new heuristic is "selected" based on the research results and the experience of Sudanese construction industry to optimize scheduling of none repetitive projects. Ultimately the balance between completing a project in minimum time while facing limited resources is achieved.

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Project No.	Project Name	Project initially planned finishing dates (Table 1)	Scheduling	Scheduling dates and Resources overloading	Leveling	New planned finishing dates (table 2) *WTC	Over allocation treatment	**New simulated finishing dates (max. date of two phases) (table 3) **WOTC**	**Resources over allocation completion**
		1	2	3	4	5	6	7	8
1-	Geological Research Center	4/10/2002	Scheduling process with time constraints condition	- Early scheduling dates are determined - resources over allocation appearance	Leveling step With 1-Time constraints condition 2- Default heuristic of simulator (primavera program) Late start + total float	4/9/2002	Over allocation treatment through: Application of heuristics to projects Using simulation techniques in two phases Without time constraints condition	**2/8/2003**	**By completion of resources over allocation treatment: simulation finishing dates** **Are gradually come back to new planned finishing dates**
2-	Marwi- Karema bridge	20/2/2009				3/1/2008		**3/9/2012**	
3-	Eldaba- Dongla road	30/6/2008				17/5/2008		**19/11/2014**	
4-	Marwi Airport	20/2/2009				20/2/2008		**29/3/2011**	
5-	National telecom. tower	16/10/2008				8/6/2008		**6/2/2012**	
6-	Tuti suspended bridge	30/6/2009				5/7/2008		**7/6/2010**	
7-	Al- Fateh tower	26/3/2006				10/8/2005		**1/9/2008**	
8-	Khart. College for Medical Sc.	4/11/2004				19/3/2003		2/9/2008	
9-	M. Science school (U.of.K.)	9/10/2001				18/9/2001		6/11/2002	
10-	Marwi Dam	25/11/2007				10/9/2007		3/10/2014	

New planned finishing dates less than projects actual dates

Appendix I: Implementation Chart

* WTC : With Time Constraints

** WOTC : Without Time Constraints

P.N.	Geological research center		Marwi karema bridge		Eldaba Dongla Read		Marwi Airport		National Tele. Corp. (PNTC)		KRT. -TUTI suspended Bridge		AL-Fateh Tower		KRT. College for Med. Sciences		M. Sciences School (U. of K.)		Marwi Dam	
P. No.>	P_1		P_2		P_3		P_4		P_5		P_6		P_7		P_8		P_9		P_{10}	
H No. v																				
H_1	Δtp_{11}	141	Δtp_{12}	1251	Δtp_{13}	2306	Δtp_{14}	1039	Δtp_{15}	1091	Δtp_{16}	502	Δtp_{17}	1082	Δtp_{18}	108	Δtp_{19}	414	$\Delta tp_{1.10}$	2546
H_2	Δtp_{21}	311	Δtp_{22}	1173	Δtp_{23}	2150	Δtp_{24}	1042	Δtp_{25}	1180	Δtp_{26}	702	Δtp_{27}	1076	Δtp_{28}	71	Δtp_{29}	408	$\Delta tp_{2.10}$	2384
H_3	Δtp_{31}	241	Δtp_{32}	997	Δtp_{33}	1631	Δtp_{34}	1009	Δtp_{35}	1338	Δtp_{36}	502	Δtp_{37}	1040	Δtp_{38}	67	Δtp_{39}	404	$\Delta tp_{3.10}$	2580
H_4	Δtp_{41}	332	Δtp_{42}	1183	Δtp_{43}	1389	Δtp_{44}	897	Δtp_{45}	1180	Δtp_{46}	285	Δtp_{47}	531	Δtp_{48}	52	Δtp_{49}	402	$\Delta tp_{4.10}$	2229
H_5	Δtp_{51}	271	Δtp_{52}	1176	Δtp_{53}	1104	Δtp_{54}	691	Δtp_{55}	1112	Δtp_{56}	494	Δtp_{57}	112	Δtp_{58}	31	Δtp_{59}	402	$\Delta tp_{5.10}$	1485
H_6	Δtp_{61}	184	Δtp_{62}	902	Δtp_{63}	880	Δtp_{64}	466	Δtp_{65}	1019	Δtp_{66}	224	Δtp_{67}	78	Δtp_{68}	43	Δtp_{69}	398	$\Delta tp_{6.10}$	752
H_7	Δtp_{71}	218	Δtp_{72}	893	Δtp_{73}	829	Δtp_{74}	355	Δtp_{75}	1029	Δtp_{76}	8	Δtp_{77}	53	Δtp_{78}	41	Δtp_{79}	398	$\Delta tp_{7.10}$	851
H_8	Δtp_{81}	141	Δtp_{82}	776	Δtp_{83}	665	Δtp_{84}	189	Δtp_{85}	1038	Δtp_{86}	7	Δtp_{87}	50	Δtp_{88}	39	Δtp_{89}	411	$\Delta tp_{8.10}$	351
H_9	Δtp_{91}	106	Δtp_{92}	759	Δtp_{93}	485	Δtp_{94}	145	Δtp_{95}	911	Δtp_{96}	12	Δtp_{97}	48	Δtp_{98}	36	Δtp_{99}	39	$\Delta tp_{9.10}$	433
H_{10}	$\Delta tp_{10.1}$	198	$\Delta tp_{10.2}$	518	$\Delta tp_{10.3}$	443	$\Delta tp_{10.4}$	110	$\Delta tp_{10.5}$	310	$\Delta tp_{10.6}$	58	$\Delta tp_{10.7}$	41	$\Delta tp_{10.8}$	28	$\Delta tp_{10.9}$	36	$\Delta tp_{10.10}$	351
H_{11}	$\Delta tp_{11.1}$	44	$\Delta tp_{11.2}$	622	$\Delta tp_{11.3}$	355	$\Delta tp_{11.4}$	25	$\Delta tp_{11.5}$	226	$\Delta tp_{11.6}$	32	$\Delta tp_{11.7}$	35	$\Delta tp_{11.8}$	20	$\Delta tp_{11.9}$	26	$\Delta tp_{11.10}$	31
H_{12}	$\Delta tp_{12.1}$	141	$\Delta tp_{12.2}$	395	$\Delta tp_{12.3}$	0	$\Delta tp_{12.4}$	6	$\Delta tp_{12.5}$	216	$\Delta tp_{12.6}$	31	$\Delta tp_{12.7}$	8	$\Delta tp_{12.8}$	12	$\Delta tp_{12.9}$	20	$\Delta tp_{12.10}$	68
H_{13}	$\Delta tp_{13.1}$	141	$\Delta tp_{13.2}$	563	$\Delta tp_{13.3}$	310	$\Delta tp_{13.4}$	129	$\Delta tp_{13.5}$	288	$\Delta tp_{13.6}$	502	$\Delta tp_{13.7}$	81	$\Delta tp_{13.8}$	57	$\Delta tp_{13.9}$	32	$\Delta tp_{13.10}$	37
H_{14}	$\Delta tp_{14.1}$	44	$\Delta tp_{14.2}$	395	$\Delta tp_{14.3}$	217	$\Delta tp_{14.4}$	26	$\Delta tp_{14.5}$	39	$\Delta tp_{14.6}$	18	$\Delta tp_{14.7}$	10	$\Delta tp_{14.8}$	53	$\Delta tp_{14.9}$	14	$\Delta tp_{14.10}$	31
H_{15}	$\Delta tp_{15.1}$	58	$\Delta tp_{15.2}$	385	$\Delta tp_{15.3}$	116	$\Delta tp_{15.4}$	25	$\Delta tp_{15.5}$	7	$\Delta tp_{15.6}$	465	$\Delta tp_{15.7}$	8	$\Delta tp_{15.8}$	46	$\Delta tp_{15.9}$	1	$\Delta tp_{15.10}$	31
H_{16}	$\Delta tp_{16.1}$	43	$\Delta tp_{16.2}$	171	$\Delta tp_{16.3}$	0	$\Delta tp_{16.4}$	10	$\Delta tp_{16.5}$	0	$\Delta tp_{16.6}$	4	$\Delta tp_{16.7}$	8	$\Delta tp_{16.8}$	12	$\Delta tp_{16.9}$	20	$\Delta tp_{16.10}$	0

Appendix II: Values of time increase (Δtp) due to application of heuristics to projects (first phase)

H. No. Heuristic Number   P. No. : Project Number   PN: Project Name

Δtp: Time increase due to the application of heuristics to projects

Δtp_{11}, Δtp_{12} .: Δtp due to the application of heuristics (1) to projects (1), (2), …. (10).

Δtp_{21}, Δtp_{22} .: Δtp due to the application of heuristics (2) to projects (1), (2), ….(10).

P.N.	Geological research center		Marawi- karema bridge		Eldaba Dongla Read		Marawi Airport		National Tele. Corp. PNTC		Khartoum - TUTI suspended bridge		AL- Fateh Tower		Khartoum College for Medical Sciences		Management Sciences School (U of K)		Marawi Dam	
P. No.>	P_1		P_2		P_3		P_4		P_5		P_6		P_7		P_8		P_9		P_{10}	
H No. v																				
H_1	Δtp_{11}	9	Δtp_{12}	301	Δtp_{13}	109	Δtp_{14}	10	Δtp_{15}	8	Δtp_{16}	437	Δtp_{17}	10	Δtp_{18}	0	Δtp_{19}	20	$\Delta tp_{1.10}$	68
H_2	Δtp_{21}	31	Δtp_{22}	301	Δtp_{23}	529	Δtp_{24}	48	Δtp_{25}	8	Δtp_{26}	221	Δtp_{27}	25	Δtp_{28}	10	Δtp_{29}	40	$\Delta tp_{2.10}$	68
H_3	Δtp_{31}	9	Δtp_{32}	301	Δtp_{33}	535	Δtp_{34}	118	Δtp_{35}	17	Δtp_{36}	221	Δtp_{37}	28	Δtp_{38}	24	Δtp_{39}	54	$\Delta tp_{3.10}$	68
H_4	Δtp_{41}	14	Δtp_{42}	301	Δtp_{43}	535	Δtp_{44}	175	Δtp_{45}	45	Δtp_{46}	221	Δtp_{47}	28	Δtp_{48}	24	Δtp_{49}	67	$\Delta tp_{4.10}$	418
H_5	Δtp_{51}	9	Δtp_{52}	301	Δtp_{53}	647	Δtp_{54}	173	Δtp_{55}	62	Δtp_{56}	434	Δtp_{57}	32	Δtp_{58}	31	Δtp_{59}	106	$\Delta tp_{5.10}$	516
H_6	Δtp_{61}	9	Δtp_{62}	301	Δtp_{63}	857	Δtp_{64}	213	Δtp_{65}	102	Δtp_{66}	221	Δtp_{67}	64	Δtp_{68}	33	Δtp_{69}	98	$\Delta tp_{6.10}$	489
H_7	Δtp_{71}	11	Δtp_{72}	362	Δtp_{73}	744	Δtp_{74}	242	Δtp_{75}	136	Δtp_{76}	221	Δtp_{77}	64	Δtp_{78}	28	Δtp_{79}	132	$\Delta tp_{7.10}$	675
H_8	Δtp_{81}	9	Δtp_{82}	630	Δtp_{83}	744	Δtp_{84}	346	Δtp_{85}	142	Δtp_{86}	221	Δtp_{87}	91	Δtp_{88}	41	Δtp_{89}	139	$\Delta tp_{8.10}$	561
H_9	Δtp_{91}	9	Δtp_{92}	657	Δtp_{93}	903	Δtp_{94}	398	Δtp_{95}	276	Δtp_{96}	221	Δtp_{97}	94	Δtp_{98}	35	Δtp_{99}	186	$\Delta tp_{9.10}$	1113
H_{10}	$\Delta tp_{10.1}$	163	$\Delta tp_{10.2}$	811	$\Delta tp_{10.3}$	1221	$\Delta tp_{10.4}$	461	$\Delta tp_{10.5}$	482	$\Delta tp_{10.6}$	459	$\Delta tp_{10.7}$	126	$\Delta tp_{10.8}$	60	$\Delta tp_{10.9}$	210	$\Delta tp_{10.10}$	1034
H_{11}	$\Delta tp_{11.1}$	9	$\Delta tp_{11.2}$	762	$\Delta tp_{11.3}$	1436	$\Delta tp_{11.4}$	542	$\Delta tp_{11.5}$	753	$\Delta tp_{11.6}$	459	$\Delta tp_{11.7}$	136	$\Delta tp_{11.8}$	55	$\Delta tp_{11.9}$	218	$\Delta tp_{11.10}$	1897
H_{12}	$\Delta tp_{12.1}$	58	$\Delta tp_{12.2}$	1173	$\Delta tp_{12.3}$	2192	$\Delta tp_{12.4}$	669	$\Delta tp_{12.5}$	755	$\Delta tp_{12.6}$	459	$\Delta tp_{12.7}$	481	$\Delta tp_{12.8}$	63	$\Delta tp_{12.9}$	224	$\Delta tp_{12.10}$	2361
H_{13}	$\Delta tp_{13.1}$	141	$\Delta tp_{13.2}$	1097	$\Delta tp_{13.3}$	2301	$\Delta tp_{13.4}$	1133	$\Delta tp_{13.5}$	818	$\Delta tp_{13.6}$	277	$\Delta tp_{13.7}$	742	$\Delta tp_{13.8}$	82	$\Delta tp_{13.9}$	204	$\Delta tp_{13.10}$	2389
H_{14}	$\Delta tp_{14.1}$	44	$\Delta tp_{14.2}$	1228	$\Delta tp_{14.3}$	2334	$\Delta tp_{14.4}$	1111	$\Delta tp_{14.5}$	900	$\Delta tp_{14.6}$	502	$\Delta tp_{14.7}$	808	$\Delta tp_{14.8}$	120	$\Delta tp_{14.9}$	204	$\Delta tp_{14.10}$	2437
H_{15}	$\Delta tp_{15.1}$	58	$\Delta tp_{15.2}$	1587	$\Delta tp_{15.3}$	2377	$\Delta tp_{15.4}$	1081	$\Delta tp_{15.5}$	1007	$\Delta tp_{15.6}$	344	$\Delta tp_{15.7}$	825	$\Delta tp_{15.8}$	130	$\Delta tp_{15.9}$	23	$\Delta tp_{15.10}$	2507
H_{16}	$\Delta tp_{16.1}$	43	$\Delta tp_{16.2}$	1705	$\Delta tp_{16.3}$	978	$\Delta tp_{16.4}$	826	$\Delta tp_{16.5}$	1091	$\Delta tp_{16.6}$	502	$\Delta tp_{16.7}$	1118	$\Delta tp_{16.8}$	167	$\Delta tp_{16.9}$	12	$\Delta tp_{16.10}$	2487

Appendix III: Values of time increase (Δtp) due to application of heuristics to projects (second phase)

H.No: Heuristic Number **P. No. : Project Number** **PN: Project Name**

Δtp: Time increase due to the application of heuristics to projects

Δtp_{11}, Δtp_{12} ;Δtp due to the application of heuristics (1) to projects (1), (2), …. (10).

Δtp_{21}, Δtp_{22} ;Δtp due to the application of heuristics (2) to projects (1), (2), …. (10).

P.N.	**Geological research center**		**Marwi karema bridge**		**EldabaDongla Read**		**Marwi Airport**		**National Tele. Corp. -PNTC**		**KRT. -TUTI suspended bridge**		**Al-Fateh Tower**		**KRT. College for Med. Sciences**		**M. Sciences School (U of K)**		**Marwi Dam**	
P. No.>	P_1		P_2		P_3		P_4		P_5		P_6		P_7		P_8		P_9		P_{10}	
P.T.C	547		1188		867		247		1005		1816		1135		428		79		862	
H No. v																				
H_1	Δtp_{11}	75	Δtp_{12}	776	Δtp_{13}	1207.5	Δtp_{14}	524.5	Δtp_{15}	549.5	Δtp_{16}	469.5	Δtp_{17}	546	Δtp_{18}	54	Δtp_{19}	217	$\Delta tp_{1.10}$	1307
H_2	Δtp_{21}	171	Δtp_{22}	757	Δtp_{23}	1337.5	Δtp_{24}	545	Δtp_{25}	594	Δtp_{26}	461.5	Δtp_{27}	550.5	Δtp_{28}	40.5	Δtp_{29}	224	$\Delta tp_{2.10}$	1226
H_3	Δtp_{31}	125	Δtp_{32}	649	Δtp_{33}	1083	Δtp_{34}	563.5	Δtp_{35}	677.5	Δtp_{36}	361.5	Δtp_{37}	534	Δtp_{38}	45.5	Δtp_{39}	229	$\Delta tp_{3.10}$	1324
H_4	Δtp_{41}	173	Δtp_{42}	742	Δtp_{43}	962	Δtp_{44}	536	Δtp_{45}	612.5	Δtp_{46}	253	Δtp_{47}	279.5	Δtp_{48}	38	Δtp_{49}	234.5	$\Delta tp_{4.10}$	1325.5
H_5	Δtp_{51}	140	Δtp_{52}	738.5	Δtp_{53}	875.5	Δtp_{54}	482	Δtp_{55}	587	Δtp_{56}	464	Δtp_{57}	72	Δtp_{58}	31	Δtp_{59}	254	$\Delta tp_{5.10}$	1000.5
H_6	Δtp_{61}	96.5	Δtp_{62}	601.5	Δtp_{63}	868.5	Δtp_{64}	339.5	Δtp_{65}	560.5	Δtp_{66}	222.5	Δtp_{67}	71	Δtp_{68}	38	Δtp_{69}	248	$\Delta tp_{6.10}$	620.5
H_7	Δtp_{71}	114.5	Δtp_{72}	627.5	Δtp_{73}	786.5	Δtp_{74}	298.5	Δtp_{75}	580	Δtp_{76}	114.5	Δtp_{77}	58.5	Δtp_{78}	34.5	Δtp_{79}	265	$\Delta tp_{7.10}$	763
H_8	Δtp_{81}	75	Δtp_{82}	703	Δtp_{83}	704.5	Δtp_{84}	267.5	Δtp_{85}	590	Δtp_{86}	114	Δtp_{87}	70.5	Δtp_{88}	40	Δtp_{89}	275	$\Delta tp_{8.10}$	456
H_9	Δtp_{91}	57.5	Δtp_{92}	705.5	Δtp_{93}	694	Δtp_{94}	271.5	Δtp_{95}	593.5	Δtp_{96}	116.5	Δtp_{97}	71	Δtp_{98}	355	Δtp_{99}	112.5	$\Delta tp_{9.10}$	773
H_{10}	$\Delta tp_{10.1}$	180.5	$\Delta tp_{10.2}$	664.5	$\Delta tp_{10.3}$	832	$\Delta tp_{10.4}$	285.5	$\Delta tp_{10.5}$	396	$\Delta tp_{10.6}$	258.5	$\Delta tp_{10.7}$	83.5	$\Delta tp_{10.8}$	44	$\Delta tp_{10.9}$	123	$\Delta tp_{10.10}$	692.5
H_{11}	$\Delta tp_{11.1}$	26.5	$\Delta tp_{11.2}$	692	$\Delta tp_{11.3}$	895.5	$\Delta tp_{11.4}$	283.5	$\Delta tp_{11.5}$	489.5	$\Delta tp_{11.6}$	445.5	$\Delta tp_{11.7}$	85.5	$\Delta tp_{11.8}$	37.5	$\Delta tp_{11.9}$	122	$\Delta tp_{11.10}$	964
H_{12}	$\Delta tp_{12.1}$	99.5	$\Delta tp_{12.2}$	784	$\Delta tp_{12.3}$	1096	$\Delta tp_{12.4}$	337.5	$\Delta tp_{12.5}$	485.5	$\Delta tp_{12.6}$	245	$\Delta tp_{12.7}$	244.5	$\Delta tp_{12.8}$	37.5	$\Delta tp_{12.9}$	122	$\Delta tp_{12.10}$	1214.5
H_{13}	$\Delta tp_{13.1}$	75	$\Delta tp_{13.2}$	830	$\Delta tp_{13.3}$	1305.5	$\Delta tp_{13.4}$	631	$\Delta tp_{13.5}$	553	$\Delta tp_{13.6}$	389.5	$\Delta tp_{13.7}$	411.5	$\Delta tp_{13.8}$	69.5	$\Delta tp_{13.9}$	118	$\Delta tp_{13.10}$	1213
H_{14}	$\Delta tp_{14.1}$	57.5	$\Delta tp_{14.2}$	811.5	$\Delta tp_{14.3}$	1275.5	$\Delta tp_{14.4}$	568.5	$\Delta tp_{14.5}$	469.5	$\Delta tp_{14.6}$	260	$\Delta tp_{14.7}$	409	$\Delta tp_{14.8}$	86.5	$\Delta tp_{14.9}$	109	$\Delta tp_{14.10}$	1234
H_{15}	$\Delta tp_{15.1}$	72	$\Delta tp_{15.2}$	985.5	$\Delta tp_{15.3}$	1246.5	$\Delta tp_{15.4}$	553	$\Delta tp_{15.5}$	507	$\Delta tp_{15.6}$	404.5	$\Delta tp_{15.7}$	416.5	$\Delta tp_{15.8}$	88	$\Delta tp_{15.9}$	12	$\Delta tp_{15.10}$	2538
H_{16}	$\Delta tp_{16.1}$	74.5	$\Delta tp_{16.2}$	938	$\Delta tp_{16.3}$	48	$\Delta tp_{16.4}$	418	$\Delta tp_{16.5}$	545.5	$\Delta tp_{16.6}$	253	$\Delta tp_{16.7}$	563	$\Delta tp_{16.8}$	89.5	$\Delta tp_{16.9}$	16	$\Delta tp_{16.10}$	1243.5

Appendix IV: Average values of time increase (Δtp) due to implementation of heuristics to projects from heuristic of two phases

P.T.C: Project time completion **H. No**: Heuristic Number **PN**: Project Name **P. No.** : Project Number

Δtp: Average time increase due to the application of heuristics to projects

Δtp_{11}, Δtp_{12} : Average Δtp due to **the application of heuristics (1)** to projects (1), (2), ... (10).

Δtp_{21}, Δtp_{22} : Average Δtp due to **the application of heuristics (2)** to projects (1), (2), ... (10).

P.N...	Geological research center		Marwi karema bridge		Eldaba Dongla Read		Marwi Airport		proj. of National Tele. Corp. - PNTC		KRT. - Tuti suspended bridge		Al-Fateh Tower		KRT. College for Med. Sciences		Manag. sciences school U.of K.		Marwi Dam	
P. No.>	P_1		P_2		P_3		P_4		P_5		P_6		P_7		P_8		P_9		P_{10}	
Δ/X	Δ	X	Δ	X	Δ	X	Δ	X	Δ	X	Δ	X	Δ	X	Δ	X	Δ	X	Δ	X
H No. v																				
H_1	Δ_{11}	0.14	Δ_{12}	0.65	Δ_{13}	1.39	Δ_{14}	2.12	Δ_{15}	0.55	Δ_{16}	0.26	Δ_{17}	0.48	Δ_{18}	0.13	Δ_{19}	2.75	$\Delta_{1.10}$	1.52
H_2	Δ_{21}	0.31	Δ_{22}	0.64	Δ_{23}	1.54	Δ_{24}	2.21	Δ_{25}	0.59	Δ_{26}	0.25	Δ_{27}	0.49	Δ_{28}	0.10	Δ_{29}	2.84	$\Delta_{2.10}$	1.42
H_3	Δ_{31}	0.23	Δ_{32}	0.55	Δ_{33}	1.25	Δ_{34}	2.28	Δ_{35}	0.67	Δ_{36}	0.20	Δ_{37}	0.47	Δ_{38}	0.11	Δ_{39}	2.90	$\Delta_{3.10}$	1.54
H_4	Δ_{41}	0.32	Δ_{42}	0.62	Δ_{43}	1.11	Δ_{44}	2.17	Δ_{45}	0.61	Δ_{46}	0.14	Δ_{47}	0.25	Δ_{48}	0.09	Δ_{49}	2.97	$\Delta_{4.10}$	1.54
H_5	Δ_{51}	0.26	Δ_{52}	0.62	Δ_{53}	1.01	Δ_{54}	1.95	Δ_{55}	0.58	Δ_{56}	0.26	Δ_{57}	0.06	Δ_{58}	0.07	Δ_{59}	3.22	$\Delta_{5.10}$	1.16
H_6	Δ_{61}	0.18	Δ_{62}	0.54	Δ_{63}	1.00	Δ_{64}	1.37	Δ_{65}	0.56	Δ_{66}	0.12	Δ_{67}	0.06	Δ_{68}	0.09	Δ_{69}	3.14	$\Delta_{6.10}$	0.76
H_7	Δ_{71}	0.22	Δ_{72}	0.53	Δ_{73}	0.91	Δ_{74}	1.21	Δ_{75}	0.58	Δ_{76}	0.06	Δ_{77}	0.06	Δ_{78}	0.08	Δ_{79}	3.35	$\Delta_{7.10}$	0.89
H_8	Δ_{81}	0.14	Δ_{82}	0.59	Δ_{83}	0.81	Δ_{84}	1.08	Δ_{85}	0.59	Δ_{86}	0.06	Δ_{87}	0.06	Δ_{88}	0.09	Δ_{89}	3.48	$\Delta_{8.10}$	0.53
H_9	Δ_{91}	0.11	Δ_{92}	0.59	Δ_{93}	0.80	Δ_{94}	1.10	Δ_{95}	0.59	Δ_{96}	0.07	Δ_{97}	0.06	Δ_{98}	0.08	Δ_{99}	1.42	$\Delta_{9.10}$	0.90
H_{10}	$\Delta_{10.1}$	0.33	$\Delta_{10.2}$	0.56	$\Delta_{10.3}$	0.96	$\Delta_{10.4}$	1.16	$\Delta_{10.5}$	0.39	$\Delta_{10.6}$	0.14	$\Delta_{10.7}$	0.07	$\Delta_{10.8}$	0.10	$\Delta_{10.9}$	1.56	$\Delta_{10.10}$	0.80
H_{11}	$\Delta_{11.1}$	0.05	$\Delta_{11.2}$	0.58	$\Delta_{11.3}$	1.03	$\Delta_{11.4}$	1.15	$\Delta_{11.5}$	0.49	$\Delta_{11.6}$	0.24	$\Delta_{11.7}$	0.08	$\Delta_{11.8}$	0.09	$\Delta_{11.9}$	1.54	$\Delta_{11.10}$	1.12
H_{12}	$\Delta_{12.1}$	0.18	$\Delta_{12.2}$	0.66	$\Delta_{12.3}$	1.26	$\Delta_{12.4}$	1.37	$\Delta_{12.5}$	0.48	$\Delta_{12.6}$	0.14	$\Delta_{12.7}$	0.22	$\Delta_{12.8}$	0.09	$\Delta_{12.9}$	1.54	$\Delta_{12.10}$	1.41
H_{13}	$\Delta_{12.1}$	0.14	$\Delta_{13.2}$	0.70	$\Delta_{13.3}$	1.51	$\Delta_{13.4}$	2.55	$\Delta_{13.5}$	0.55	$\Delta_{13.6}$	0.21	$\Delta_{13.7}$	0.36	$\Delta_{13.8}$	0.16	$\Delta_{13.9}$	1.5	$\Delta_{13.10}$	1.41
H_{14}	$\Delta_{12.1}$	0.11	$\Delta_{14.2}$	0.68	$\Delta_{14.3}$	1.47	$\Delta_{15.4}$	2.30	$\Delta_{14.5}$	0.47	$\Delta_{14.6}$	0.14	$\Delta_{14.7}$	0.36	$\Delta_{14.8}$	0.20	$\Delta_{14.9}$	1.4	$\Delta_{14.10}$	1.43
H_{15}	$\Delta_{12.1}$	0.13	$\Delta_{15.2}$	0.83	$\Delta_{15.3}$	1.44	$\Delta_{15.4}$	2.23	$\Delta_{15.5}$	0.50	$\Delta_{15.6}$	0.22	$\Delta_{15.7}$	0.37	$\Delta_{15.8}$	0.21	$\Delta_{15.9}$	0.15	$\Delta_{15.10}$	2.94
H_{16}	$\Delta_{12.1}$	0.14	$\Delta_{16.2}$	0.79	$\Delta_{16.3}$	0.56	$\Delta_{16.4}$	1.69	$\Delta_{16.5}$	0.54	$\Delta_{16.6}$	0.14	$\Delta_{16.7}$	0.50	$\Delta_{16.8}$	0.21	$\Delta_{16.9}$	0.2	$\Delta_{16.10}$	1.44

Appendix V: The percentage of average values of time increase (Δtp) due to implementation of heuristics to projects

H.No. Heuristic Number **P. No.**: Project Number **PN**: Project Name

Δ: Percentage value of time increase to projects time completion.

Δ_{11}, Δ_{12}.: Percentage value of time increase to projects time completion due to **the application of heuristics (1)** to projects (1), (2), …. (10).

Δ_{21}, Δ_{22}: Percentage value of time increase to projects time completion due to **the application of heuristics (1)** to projects (1), (2), …. 1(10).