Application of Multi-technique in Project Planning to Solve Time-cost Trade-off Problem

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Abstract: One of the most important problems in project management is the time-cost trade-off problem (TCTP) that must be taken into consideration during project planning and control process through the use of suitable planning techniques. This study presented a model aims to solve (TCTP) using crashing as a traditional project planning technique and concurrency technique with activities partitioning in addition to new suggested technique that mixes between the two techniques and named as Concurrency-with Partitioning and Crashing Technique (CPCT). The model focuses on minimizing project time and cost and it is applied on an adopted case study. The results show that the suggested (CPCT) produces the best results for the two objectives compared to other applied techniques.

Keywords: project planning; time-cost trade-off problem; multi-technique; crashing technique; concurrency technique.

I. INTRODUCTION

Small and large-size projects have certain objectives to be achieved such as time, cost, resources, performance, scope, etc. that require planning, scheduling and control processes. These processes are considered to be important in the field of management and execution of projects, especially those that need coordination, large effort and long execution time. These processes could be applied through utilization of various project planning tools and techniques.

Project planning process involves four separate purposes:
- Cost and project duration determination as well as enabling the decision-making, in order to force the decision to go ahead with the project from the beginning.
- Required resources level determination.
- Work assigning and project progress monitoring assisting.
- Helping in estimating the effect of any altering to the project [1].

After completing planning process on work activities, scheduling process is lunched in order to determine the duration for these activities. This process includes representation of sequences and phases of individual activities required to complete work execution [2]. Time-Cost Trade-off Problem (TCTP) occurs when the change in project execution time could effect on the project cost; that is, decreasing in project execution time leads to an increasing in the total project cost and vise versa [3]. This problem could be solved through utilizing some of project management tools and techniques, following are a number of them:
Gantt chart is the method that is used to show progression of the project graphically. Project management could be performed simply if it is observed as small manageable entities where the dependencies are visibly cleared,

parallel processes are detected, project progression can be tracking, and total processing durations are determined [4]. CPM/PERT are two closely related tools used to help project manager in performing the activities of developing a realistic schedule, and monitoring the progress of the project. PERT is an (Program Evaluation and Review Technique) and CPM is (Critical Path Method) [5].
Crashing technique can be defined as a particular type of compression techniques related with scheduling problems. This technique involves decreasing the total duration of project scheduling for an activity or activities after taking a number of alternatives to be analyzed for determining a way to get the maximum duration compression of schedule for the least added cost. There are a number of approaches for crashing a project schedule, including duration reduction of schedule activity as well as increasing resources assignment related with schedule activities [6].
Concurrent engineering is considered to be a systematic method that combines the primary idea of a project with its applied research, development, design, production, marketing, distribution, and sales. This method produces more effective and shorter design cycle while keeping product reliability and improving its quality through compression the schedule to permit simultaneous or overlap performing of many activities [7].

II. LITERATURE REVIEW

This section presents different studies published in the last years that employee different methods for solving the (TCTP):
Ding et al. (2010) [8]: they have presented a developed approach for solving the TCTP under imprecise conditions as a project scheduling problem using trapezoidal fuzzy numbers. The proposed model has estimated total

completion cost within investment penalty cost and provided more choices for the decision maker. In order to expand the scale of calculation, multi-objective genetic algorithm (MOGA) has been applied.

Sahu, K. and Sahu, M. (2014) [9]: they have presented time management with optimum cost by means of crashing. An alternative approach has been given in order to get optimal cost and time in addition to minimum duration for the project with totally crashing in the critical path. The proposed method has been performed by directly minimizing the critical slope value hence minimizing the duration of the project. The results of this study have given such a preferable crashing values in addition to manage the time effectively. Al Haj, Rana A., and Sameh M. El-Sayegh (2015) [10]: they have presented a model of nonlinear integer programming to solve the (TCTP) by taking into account the effect of total float-loss. In order to get a suitable solution for this problem, What'sBest solver package within Microsoft Excel has been used, and the computed total float-waste cost was combined based on the float-commodity method. The results from this study have focused on enabling project managers in examining the (TCTP) thus reaching certain project objectives.

III. PROPOSED MODEL

The proposed model presents an approach for solving TCTP through utilizing multiple project planning and control techniques. This model includes mathematical problem description using tools and project representation techniques to deal with activities and project data in an engineering manner, project planning and control techniques are applied for obtaining multi-objective results. Four stages are used to define this model.

Stage 1: defining planning and scheduling inputs required for the problem including:
- Number of activities (N).
- Activity symbol (A_i, where i = (1,2, 3, …., N)
- Activity Duration (D_i).
- Activity Precedencies (APi).
- Activity Cost (AC_i)
- Indirect Cost per day ($IC_{/d}$).
- Direct Cost per day ($DC_{/d}$).
- Estimated project budget (EC).
- Project Duration (PD).
- Total Project Time (T).
- Total Project Cost (C).

Stage 2: Identifying project planning and control objectives, where in this stage two objectives are determined:
- Time: Project delivery within or less than the specified time.
- Cost: Project delivery within or less than the estimated budget.

Stage 3: Inputs representation using Gantt Chart and CPM network, where in this stage project activities are represented according to Fig. 1. The following abbreviations could be defined as follows:

- Indirect activity Cost (IC).
- Direct and Indirect Activity Cost (DI_i).
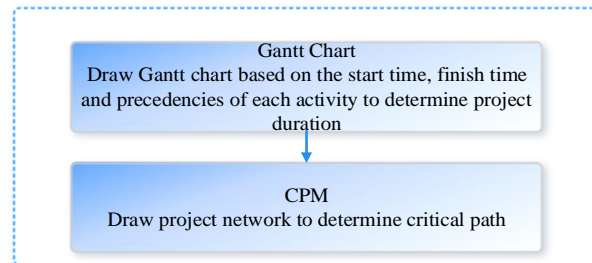- Total Project Cost (TC).

Fig. 1. Representation of project duration by Gantt chart and CPM

Stage 4: Applying multi-technique as project planning alternatives, where in this model, some of these techniques are applied; these are:

A. Crashing Technique

The main steps of crashing technique can be described as shown in Fig. 2. The following abbreviations could be defined as follows:
- Normal Time (NT).
- Crashing Time (CT).
- Normal Cost (NC).
- Crashing Cost (CC).
- Cost Slope (CS).
- Indirect Project Cost (IPC).
- Project Duration (PD).
- Project Direct Cost (DC).
- Crashing Cost Slope (Ccslop).
- Crashing Cost Slope Cumulative (CCp).
- ΔT of The New Activity (ΔTn).
- CS of The New Activity (CSn).

B. Concurrency Technique with Partitioning (CP)

This technique is applied in project planning process with the aid of Gantt chart; where the total project execution time is reduced through planning and execution of some of project activities concurrently after partitioning some of them if they need without affecting on the rest of the activities in terms of their precedencies and execution time. These activities are also executed within their defined time. Fig. 3 describes the main steps that are applied in this technique.

C. Concurrency-Partitioning and Crashing Technique (CPCT)

The researcher suggests a new approach that mixes between two techniques, concurrency and crashing after partitioning some of project activities. This approach is named as Concurrency-Partitioning and Crashing technique (CPC). The purpose of this combination is to be considered as an addition alternative that could be compared with other applied techniques in order to facilitate the process of decision-making. Fig. 4 shows the main steps of applying this approach.

IV. MODEL IMPLEMENTATION

An industrial construction project is taken as a case study. The project involves construction of steel warehouse to protect large equipment used for engine production in heavy industry.

After drawing project network and Gantt Chart depicted in Fig. 5 and Fig. 6 respectively; project duration was 184 days; the direct cost was 4460 $, and the indirect cost was 80 $ per day. Normal and crash durations in addition to normal and crash cost with their corresponding activities are illustrated in table I.
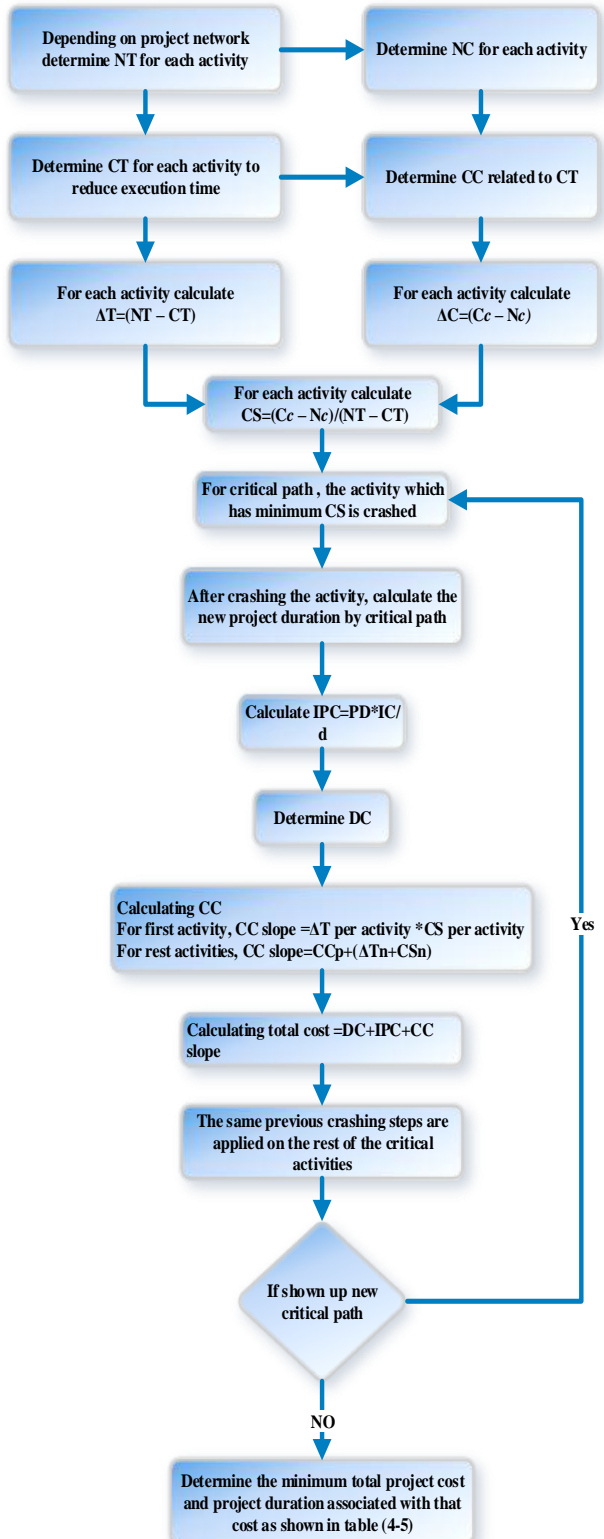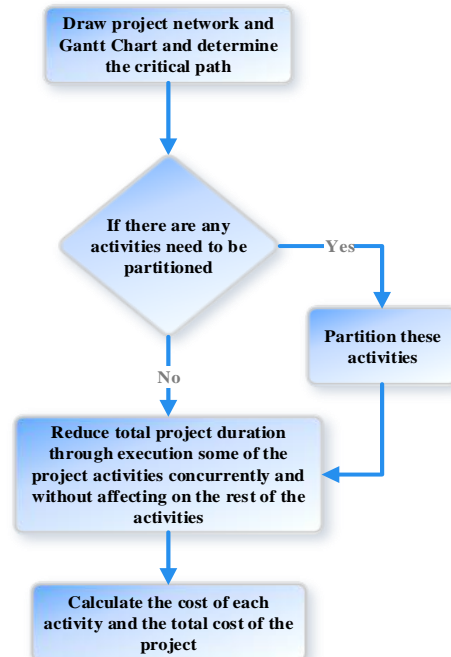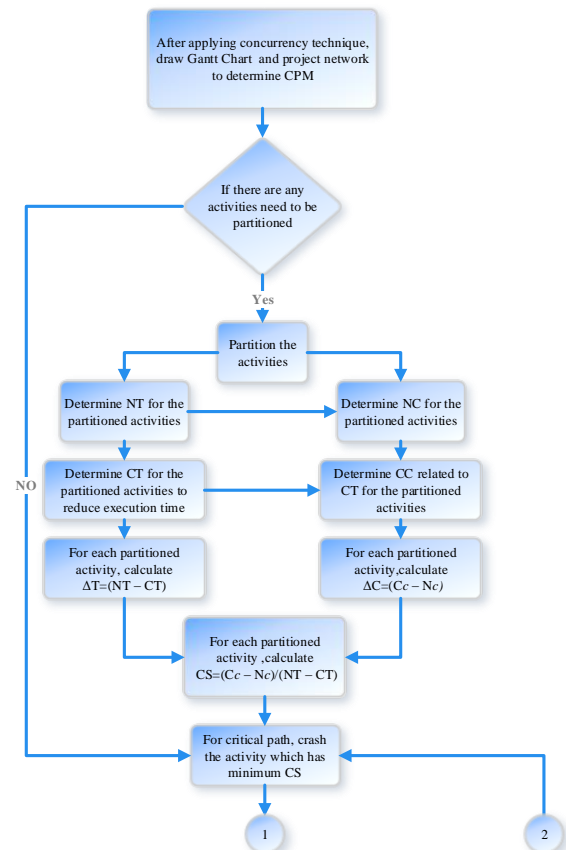

Fig. 2. Flowchart of crashing technique steps

Fig.3. Flowchart of (CP) technique
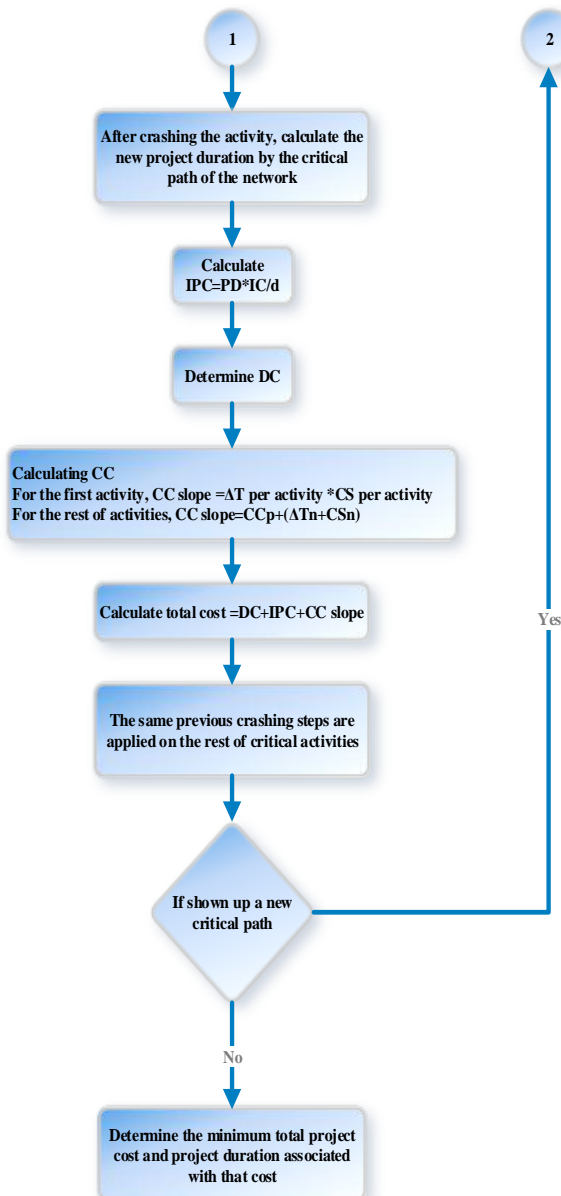
Fig. 4. Flowchart of the suggested approach (CPCT)

TABLE I: Information of the Case Study

A_i	AP_i	NT (day)	NC ($)	CT (day)	CC ($)	CS
A	-----	30	100	20	200	10
B	A	20	30	15	50	4
C	B, E	30	400	20	600	20
D	A	10	30	6	50	5
E	A	14	150	10	230	20
F	A	30	120	25	195	15
G	D, E	20	90	12	154	8
H	D, E	80	160	50	370	7
I	D, E	90	280	50	520	6
J	F, E	10	600	5	720	24
K	G, J	30	1200	25	1500	60
L	K, H	20	150	15	350	40
M	C, L	5	200	5	200	0
N	M, I	20	800	12	1200	50
O	N	15	150	10	210	12

Fig. 5. Planned project network

Following is a list of project activities and their corresponding symbols:

A   Preparations
B   Order machine
C   Deliver machine
D   Order building materials
E   Preparatory works on site
F   Conveyance of bulldozers
G   Delivery of gravel and cement
H   Delivery of mount structure
I   Delivery of prefabricated steel structure
J   Groundwork
K   Foundation for the depot
L   Placing the mount for the machine
M   Placing the machine on the mount
N   Assembling the building structure
O   Finishing works, project delivery
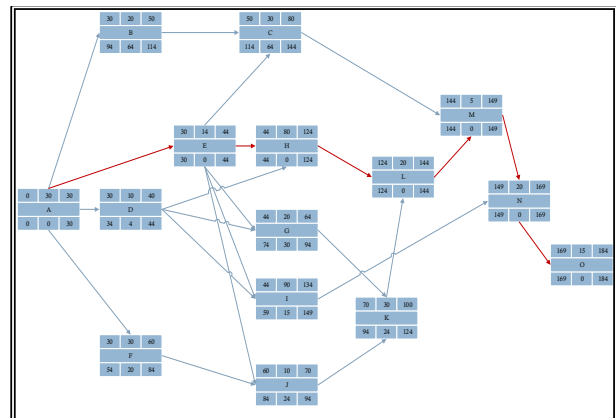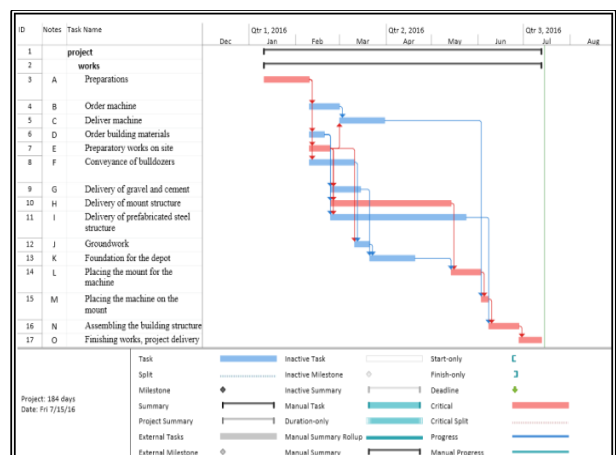

Fig. 6. Planned project duration

In this case study, three techniques have been applied. The first one was the crashing technique, in which the critical activities have been crashed according to the availability of crashing information in table I and as shown in table II, where the resulted duration was 122 days while the cost was 15,769 $.

The second was the concurrency technique with partitioning (CP), in which, activity A has been partitioned into two parts; A and A1, where activity F has been made to be executed concurrently with the second part A1. Table III illustrates the partitioning activity and application of concurrency technique. Gantt Chart and project network are illustrated in Fig. 7 and Fig. 8 respectively. The chart describes overlapping process among activities while the network is used to determine project execution time that was 180 days in addition to the project cost that was 18860 $.

The third technique was the suggested mixed approach (CPCT). Depending on (CP) results and its network and information available in table III; the activities have been crashed as demonstrated in table IV.
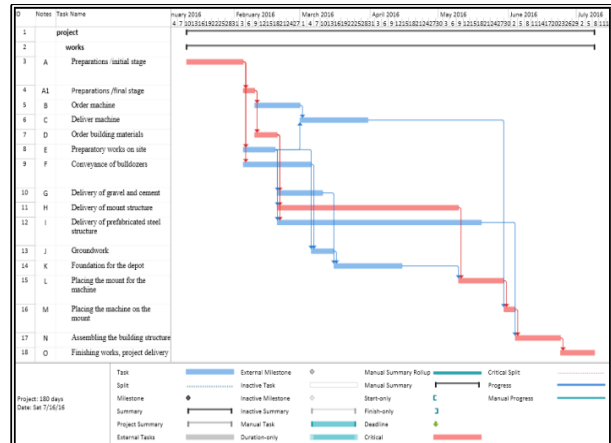

Fig. 7. Gantt Chart of (CP) technique

TABLE II: Project activities after crashing

path	activity crashed	ΔT	day saved in project	(PD)/ day	normal direct cost (DC)	(CCp)	(IPC)	total cost
CPM1	--	--	--	184	4460	0	14720	19180
CPM1	H	30	15	169	4460	210	13520	18190
CPM2	I	40	9	160	4460	450	12800	17710
CPM3	A	10	10	150	4460	550	12000	17010
CPM3	O	5	5	145	4460	610	11600	16670
CPM3	F	5	5	140	4460	685	11200	16345
CPM3	J	5	1	139	4460	805	11120	16385
CPM4	G	8	0	139	4460	869	11120	16449
CPM1	E	4	4	135	4460	949	10800	16209
CPM1	L	5	5	130	4460	1149	10400	16009
CPM1	N	8	8	122	4460	1549	9760	15769
CPM3	K	5	0	122	4460	1849	9760	16069

TABLE III: Project activities after application of (CP) technique

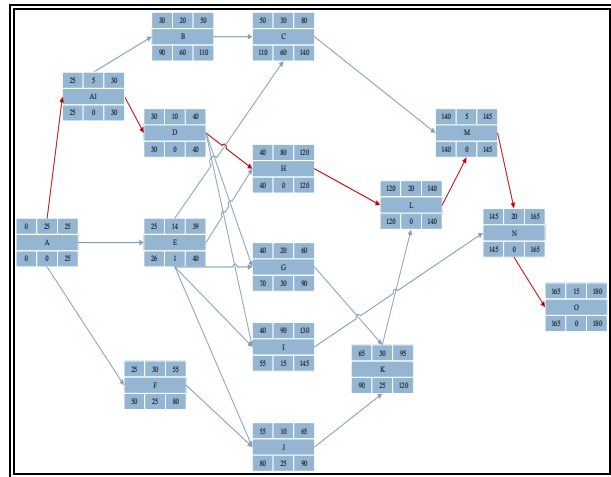| A_i	AP_i	NT (day)	NC ($)	CT (day)	CC ($)	CS
A	-----	25	83	17	160	9.63
A1	A	5	17	3	40	11.5
B	A1	20	30	15	50	4
C	B, E	30	400	20	600	20
D	A1	10	30	6	50	5
E	A	14	150	10	230	20
F	A	30	120	25	195	15
G	D, E	20	90	12	154	8
H	D, E	80	160	50	370	7
I	D, E	90	280	50	520	6
J	F, E	10	600	5	720	24
K	G, J	30	1200	25	1500	60
L	K, H	20	150	15	350	40
M	C, L	5	200	5	200	0
N	M, I	20	800	12	1200	50
O	N	15	150	10	210	12

Fig. 8. Project Network of (CP) technique

TABLE IV: Project activities after crashing for (CPCT)

Path	activity crashed	ΔT	day saved in project	(PD)/ day	normal direct cost (DC)	(CCp)	(IPC)	total cost
CPM1	--	--	--	180	4460	0	14400	18860
CPM1	D	4	1	179	4460	20	14320	18800
CPM2	H	30	15	164	4460	230	13120	17810
CPM3	I	40	9	155	4460	470	12400	17330
CPM4	A	8	8	147	4460	547	11760	16767
CPM4	O	5	5	142	4460	607	11360	16427
CPM4	F	5	5	137	4460	682	10960	16102
CPM4	J	5	1	136	4460	802	10880	16142
CPM5	G	8	0	136	4460	866	10880	16206
CPM2	E	4	3	133	4460	946	10640	16046
CPM1	A1	2	1	132	4460	969	10560	15989
CPM2	L	5	5	127	4460	1169	10160	15789
CPM2	N	8	8	119	4460	1569	9520	15549
CPM4	K	5	5	119	4460	1869	9520	15849

V. DISCUSSION AND EVALUATION

The suggested (CPCT) results were 119 days for project duration and 15549 $ for project cost. Accordingly, this approach presented minimum time and cost compared with the other two techniques in addition to (CPM) network of the original plan, so that, the suggested (CPCT) approach could be considered the most effective technique in solving (TCTP). Table V demonstrates the final comparison between the applied techniques.

TABLE V: Comparison among the applied techniques

Technique	Time (days)	Cost ($)
CPM	184	19180
Crashing	122	15769
CP	180	18860
CPCT	119	15549

VI. CONCLUSIONS

The model has been suggested to solve time-cost trade-off problem and it could be applied to help project management in planning and scheduling processes for different types of projects.

Three techniques have been applied as alternatives these are crashing, concurrency technique with partitioning, and a new suggested approach combines between concurrency technique with partitioning and crashing technique which is named as concurrency-partitioning and crashing technique. The results have shown that the suggested mixed approach was the best one among other techniques.

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