Tibuana
Journal of applied Industrial Engineering-University of PGRI Adi Buana
p-ISSN 2622-2027
DOI : 10.36456/tibuana.6.2.7757.109-118 *e*-ISSN 2622-2035

Analysis of time and cost using time cost trade off method in pressure vessel project

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***Abstract* - One of the construction companies got a Pressure Vessel project job. During the process of working on the project, it was delayed from the predetermined date so that the company had to pay a fine of 0.2% every day. So it is necessary to analyze project scheduling in order to get the optimal time and cost of working on this project. The methods used in this research are Time Cost Trade Off (TCTO), Precedence Diagram Method (PDM) and crashing. Acceleration is carried out on all critical paths contained in fabrication activities. This study uses alternatives to accelerate the addition of 50% and 75% labor. The results of this study obtained the optimal time and cost with the alternative of adding 75% labor. The resulting acceleration duration is 75 days faster than the actual duration, with costs incurred of Rp. 161,386,836, -, resulting in a 56% decrease from the actual duration cost of Rp. 286,961,745, -. Analysis of the S-curve found that the accelerated duration can be completed faster than the actual duration because, the curve line on the accelerated duration is more sloping closer to the y-axis indicating greater progress each week.**

***Keywords*; Crashing, Pressure Vessel, Project Management, Time Cost Trade Off**

I. INTRODUCTION

According to Dannyanti (2010) a construction project is an activity that aims to erect a building that requires resources, both costs, labor, materials and equipment.Meanwhile, according to Andhika (2017) a project is an effort to achieve certain goals that are limited by time and available resources.In a construction project, there are three important things that must be considered, namely time, cost, and quality (Kerzner, 2006). Scheduling is very necessary in the work of a project to manage the length of time of the project process, so as not to experience delays and avoid cost overruns.Project scheduling is an activity to determine each stage of work related to the resources needed by the project, which includes the number of workers, costs and the amount of supplies needed for certain activities and those related to other activities (SofjanAssauri, 2016). Project management is needed in the work of a project as for the functions of project management are as Planning, Organization, Actuating and Controlling (Dimyati and Nurjaman, 2014).

In this study will discuss the pressure vessel project where in actual workmanship this project actually experienced delays from the deadline that has been set,the delay resulted in the company having to pay a fine of 0.2% per day and a decrease in client confidence inthe company's performance. There are many factors that cause delays in the project, for example a lack of labor and the company running several projects at one time. Therefore, it is necessary to analyze the actual time and cost. In this study, the Time Cost Trade Off method, Precedence Diagram Method (PDM) and crashing were used. In order to get the optimal time and cost, the alternative used in this study is the addition of Labor. Then after acceleration, compare the time and cost before and after acceleration using the S-curve.

In this research does not discuss the addition of machines, when working on the project the state of the machine is in a normal position, crashing is carried out in the fabrication process.

II. RESEARCH METHODOLOGY

According to Satrijo&Habsya (2012) a pressure vessel is a place or container to store or hold a fluid, either in the form of a gas or a liquid. place or container to store or

p-ISSN 2622-2027
DOI : 10.36456/tibuana.6.2.7757.109-118 *e*-ISSN 2622-2035

accommodate a fluid, either in the form of a liquid or gas. liquid or gas.

2.1 Work Breakdown Structure *(WBS)*

The first step is to group the project into a more detailed form in the form of smaller sub-components or activities to make it easier to work on. work breakdown structure is a fundamental management tool that defines projects through a level of activities that can be clearly identified, managed and controlled (Benny,2004).After analyzing the WBS, then analyze the dependency relationship of each activity or called the Work Network. According to Muhardi (2011) Network planning or work network is a project planning and control that describes the dependency relationship between each job described in the network diagram (Network Planning)

2.2 Precedence Diagram Method (PDM)

Precedence Diagram Method (PDM) is a work network that is included in the classification of activity on node (AON) where in the AON network nodes indicate an activity and arrows indicate the relationship between the activities concerned (Soeharto, 1999) which are generally square nodes. According to Ervianto (2005), the advantages of Precedence Diagram Method (PDM) compared to CPM is that PDM does not require dummy so that making the network simpler. This is because different overlapping relationships can be created without increasing the number of activities (Arianto, 2010). In PDM, there is also aconstraint that one constraint can only connect two nodes, because each node has two ends, namely the initial end or start (S) and the final end or finish (F).

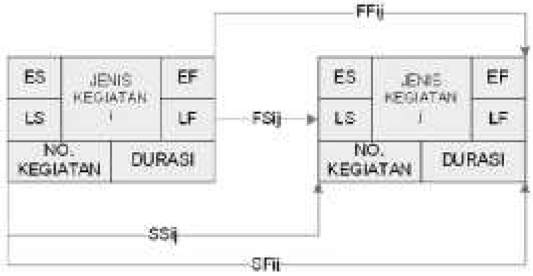

Figure 1. Relationship between activities i and j (Ervianto, 2005)

Based on Figure 1, it can be seen that in the PDM method there are 4 constraints, which consist of: Finish to Start (FS), Start to Start (SS), Finish to Finish (FF), and Start to Finish (SF).

To accelerate the duration, a new duration calculation is carried out for each activity with equations 1,2,3.

Normal productivity $= \frac{W \quad V_i}{N \quad D}$ …(1)

Crash Producticvity =
$$\frac{p \ (m \quad n \quad + m \quad c \quad h)}{m \quad n}$$ …(2)

Crash Duration =
$$\frac{W \quad V_i}{C \quad h \, P_i}$$ ….(3)

2.3 Project Cost

Project costing is a written and systematic plan of activities that require the expenditure of costs for all activities used to achieve a project.According to Soeharto (1995) there are several types of costs associated with financing a construction project, namely:

1. Direct cost.
   Direct costs are all costs directly related to the implementation of construction project work in the field.
2. Indirect Cost.
   Indirect costs are project costs that are not directly related to the project, in this case not directly in contact with project work activities.

2.4 Cost Slope

Cost Slope is the ratio between the increase in cost and the acceleration of project completion time, The way to calculate the cost slope is as follows:

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e-ISSN 2622-2035

Cost Slope = $\frac{c \quad hc \quad -n \quad c}{N \quad D \quad -cr \quad hD}$ …(4)

2.5 Time Cost Trade Off

Time cost trade off method is analytical method used to accelerate the project completion time by compressing the schedule to get a more profitable project in terms of time (duration), and cost (Florensia, 2016). This scheduling acceleration aims to find how much time and cost it takes to complete the project according to the target efficient and best plan.The alternative used in this study is the addition of 50% and 75% labor of the normal labor force.The optimum addition of labor will increase work productivity due to too narrow an area to work (Wibowo, 2020).With minimum resource utilization and optimum completion time, activities will be completed at normal cost and normal duration (Pratama, 2015).In addition, it must also be noted that the emphasis is only on activities on the critical path (Mahapatni 2019).

2.6 S-curve

Husen (2010) argues that the S-curve can determine progress based on activities, time and work weights that are represented as a cumulative percentage of all project activities. all project activities S-curve visualization can provide information about the progress of progress of the project by comparing it to the schedule.

III. RESULT AND DISCUSSION

3.1 Work Breakdown Structure

In this final project, we will discuss the work of the pressure vessel project weighing 1913 kg because this work has experienced delays that must be rescheduled and optimized. The following is the Work Breakdown Structure (WBS) of the work on the pressure vessel projectcan be seen in figure 2.

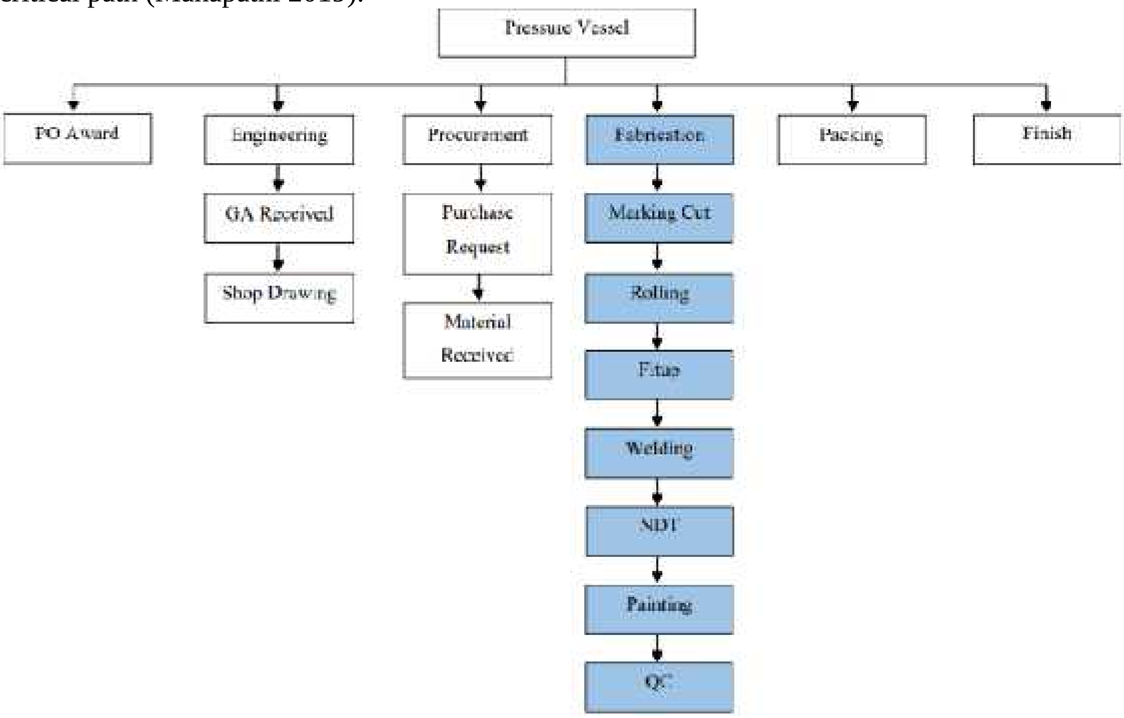

Figure 2. Pressure vessel WBS

3.2 Precedence Diagram Method (PDM)

In planning and working on a project, each company has a different planning system. Table 1 below is a grouping of Pressure Vessel project activities and durations based on the actual duration of the project.

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Table 1. Activity Grouping and Actual Schedule Duration

Kode	**Nama Kegiatan**	**Durasi (Hari)**	***Predecessor***
	Pressure Vessel	171	
A	PO *Award*	1	
B	*Engineering*		
	GA Received	7	A
	Shop drawing	18	B1
C	*Procurement*		
	Purchase request	15	B1 FS
	Material received	40	C1 FS - 2
D	*Fabrication*		
	Marking Cut	38	C1
	Rolling	41	D1 FS - 16
	Fitup	44	D2 FS - 13
	Welding	22	D3 FS - 15
	NDT	5	D4 FS
E	*Painting*		
	Blasting Primer	2	D5FS – 1
	Top Coat	1	E1 FS - 1
F	QC	71	D1 SS + 7
G	*Packing*	1	E2
H	*Delivery (Finish)*	2	G

According to Render and Jay (2006), the critical path is a series of activities of a project that cannot be delayed and shows an interrelated relationship with each other.. So that activities that are on the critical path have more attention than non-critical activities. The critical path is characterized by a slack or float value equal to zero.The slack value can be calculated using :
LF EF = LS ES = 0
Forward and backward calculations for activities with sequential actual durations can be seen in Table 2.

Table 2. Critical Activities on the Actual Schedule

code	Duration	Earliest ES	Earliest EF	Latest LS	Latest LF	Total Slack	Description
	171						
A1	1	0	1	0	1	0	Kritis
B1	7	1	8	1	8	0	Kritis
B2	18	8	26	53	71	45	Tidak
C1	15	5	20	5	20	0	Kritis
C2	40	31	71	30	71	0	Kritis
D1	38	61	99	61	99	0	Kritis
D2	41	83	124	83	124	0	Kritis
D3	44	111	155	111	155	0	Kritis
D4	22	140	162	140	162	0	Kritis
D5	5	162	167	162	167	0	Kritis
E1	2	166	168	166	168	0	Kritis
E2	1	167	168	167	168	0	Kritis
F	71	68	97	139	168	29	Tidak
G	1	168	169	168	169	0	Kritis
H	2	169	171	169	171	0	Kritis

Can be known the total completion time pressure vessel project on the actual schedule in the field reached 171 days experiencing a delay of 75 days from the actual duration. On

p-ISSN 2622-2027
e-ISSN 2622-2035
DOI : 10.36456/tibuana.6.2.7757.109-118

the critical path with activities: A-B1-B2-D1-D2-D3-E-F-G-I. Figure 3 below is the critical path contained in the pressure vesse project.

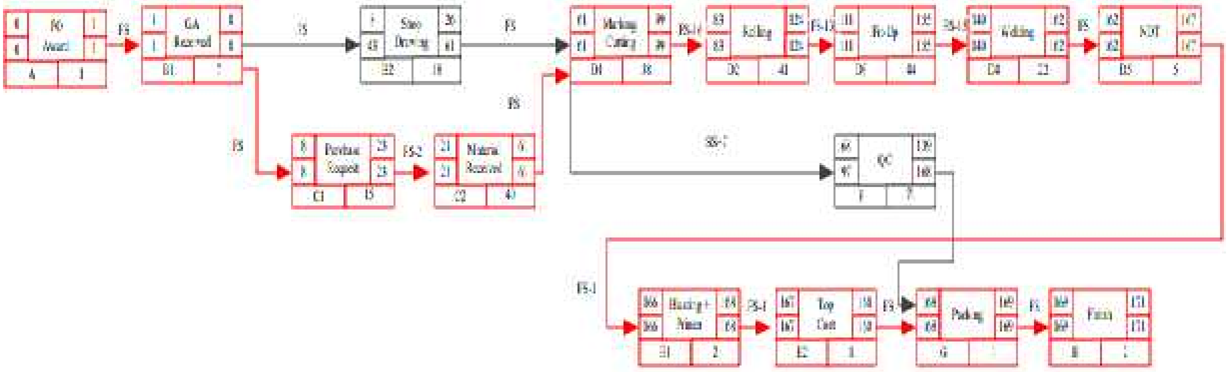

Figure 3. PDM Network for Actual Schedule

3.3 Additional manpower

The ideal project work area for each labor is defined as follows:

$$\text{Ideal Working Area} = \frac{1 \quad +2}{2} = 150 \text{ ft}^2/\text{manpower}$$

$$= 150 \text{ ft}^2/\text{manpower} \times 0{,}0929$$

$$= 13{,}935 \text{ m}^2/\text{manpower}$$

From the work area, it can be known how many additional ideal workers for each activity Can be seen in table 3.

Table 3. Ideal manpower Quantity

code	Working Area (m^2)	Ideal workforce (people)
A	-	-
B	-	-
	-	-
C	-	-
	-	-
D1	82,500	5,92 ≈ 6
D2	115,525	8,3 ≈ 8
D3	108,512	7,8 ≈ 8
D4	78,612	5,6 ≈ 6
D5	112,548	8,08 ≈ 8
E1	65,672	4,7 ≈ 5
E2	54,237	3,9 ≈ 4
F	-	-
G	-	-
H	-	-

1. Crash Duration with Alternative Manpower Addition.

After getting the ideal additional labor for each activity, then calculate the new duration for each accelerated activity. The calculation of the new duration is done by calculating productivity first.The calculation uses equations 1, 2, 3 and the results can be seen in table 4 below. Not all activities can be accelerated.Table 4 is the result of the new duration of the additional 50% manpower.

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DOI : 10.36456/tibuana.6.2.7757.109-118 *e*-ISSN 2622-2035

Table 4. Crash Duration Calculation with 50% Manpower AddAlternative

code	Normal Man power	*Crash* Man power	Produktivitas Normal	ProdukTivitas *Crash*	*Crash Duration*
D1	2	3	50,34	75,51	25,3 ≈
D2	2	3	46,659	69,99	25
D3	2	3	43,477	65,22	69,3 ≈
D4	2	3	86,955	130,43	27
D5	4	6	382,6	573,9	29,3 ≈
					29
					14,7 ≈
					15
					3,33 ≈ 3
E1	2	3	956,5	1434,75	1,33 ≈ 1
E2	1	2	1913	3826	0,5 ≈ 1

The new duration with 75% additional manpower can be seen in Table 5.

Table 5. Crash Duration Calculation with 75% Manpower AddAlternative

code	Normal Man power	*Crash* Man power	Produktivitas Normal	ProdukTivitas *Crash*	*Crash Duration*
D1	2	4	50,34	100,68	19,0 ≈
D2	2	4	46,659	93,32	19
D3	2	4	43,477	86,95	20,5 ≈
D4	2	4	86,955	173,91	21
D5	4	7	382,6	669,55	22,0 ≈
					22
					11,0 ≈
					11
					2,9 ≈ 3
E1	2	4	956,5	1913,00	1,0 ≈ 1
E2	1	2	1913	3826,00	0,5 ≈ 1

2. Crash Cost with Alternative Addition Manpower.

After getting the next acceleration duration, namely calculating the crash cost of the alternative addition of manpower by multiplying the total workers by the hourly rate of the manpower concerned. According to Frederika in (Ariyanto et al, 2020), using the Crash Schedule of course the cost will be much greater than the Normal Schedule.The calculation results for the addition of 50% manpower can be seen in Table 6.

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DOI : 10.36456/tibuana.6.2.7757.109-118 *e*-ISSN 2622-2035

Table 6. Crash cost with 50% manpower Addition Alternative

code	Normal duration	manpower	Manpower cost (Rp)
D1	25	3	15.000.000
D2	27	3	16.200.000
D3	29	3	17.052.000
D4	15	3	9.300.000
D5	3	6	3.708.000
E1	1	3	572.000
E2	1	2	384.000

Table 7 is the direct manpower cost in accelerating the duration with the addition of 75% manpower.

Table 7. Crash cost with 75% manpower Addition Alternative

code	Normal duration	manpower	Manpower cost (Rp)
D1	19	4	15.200.000
D2	21	4	16.548.000
D3	22	4	17.072.000
D4	11	4	9.020.000
D5	3	7	4.272.000
E1	1	4	760.000
E2	1	2	384.000

3. Cost Slope

Cost Slope is the ratio between the increase in cost and the acceleration of project completion time,To find the cost slope value, equation 4 is used, Table 8 is the result of the cost slope calculation for additional manpower of 50%.

Table 8. Order of Cost Slope and Duration Acceleration with 50% Manpower Addition

code	**Cost Slope (Rp)**	**Normal Duration**	**Crash duration**	**Crash duration**
E1	- 188.000	2	1	170
D5	- 156.000	5	3	168
D1	- 15.385	38	25	155
D3	- 1.333	44	29	140
D2	20.857	41	27	126
D4	58.857	22	15	119
E2	192.000	1	1	119

The cost slope value on accelerating the project duration with the addition of 50% manpower can be seen in table 9.

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Table 9. Order of Cost Slope and Duration Acceleration with 75% Manpower Addition

code	Cost Slope (Rp)	Normal Duration	Crash duration	Crash duration
D1	0	38	19	152
D3	0	44	22	130
E1	0	2	1	129
D4	12.000	22	11	118
D2	32.000	41	21	98
D5	84.000	5	3	96
E2	192.000	1	1	96

In the addition of 75% labor, the normal duration of 171 days becomes 96 days or the same as the planned duration. In this study, the software used for duration calculation is Microsoft Project. So in this study, an alternative 75% of additional manpower is taken for the optimum time and cost.

3.4 Total Cost

The total direct and indirect costs for normal duration can be seen in table 10.

Table 10. Total Cost of Normal Duration

No	Direct Costs	Total Cost (Rp)
1	Direct manpower Cost	62.040.000
2	Material Cost	12.603.000
	indirect Costs	
3	Indirect manpower Cost	149.854.545
4	Machine Operating Cost	4.975.000
5	Other Additional Cost	1.117.800
6	Consumable Cost	18.871.400
	Cost Penalty	37.500.000
	Total Cost	286.961.745

The accelerated duration with 75% additional manpower can be seen in Table 11.

Tabel 11. Total Durasi BiayadenganPenambahan Tenaga Kerja 75%

No	Direct Costs	Total Cost (Rp)
1	Direct manpower Cost	63.256.000
2	Material Cost	12.603.000
	indirect Costs	
3	Indirect manpower Cost	60.563.636
4	Machine Operating Cost	4.975.000
5	Other Additional Cost	1.117.800
6	Consumable Cost	18.871.400
	Total Cost	161.386.836

From the results of the calculation, a new duration is obtained with an alternative of adding 75% of the manpower, the results for the crash duration are the same as the planned duration of 96 days. In the acceleration duration there is a difference of 75 days from the actual duration. The total cost incurred on the alternative of adding 75% of the manpower has decreased by 56% from the total cost on the actual schedule with a difference of Rp.125,574,909, -.

3.5 S-curve.

Husen (2010) explains that the S-curve is graphically a depiction of cumulative work

p-ISSN 2622-2027
DOI : 10.36456/tibuana.6.2.7757.109-118 *e*-ISSN 2622-2035

progress (weight %) on the vertical axis against time on the horizontal axis. The actual duration curve line slopes closer to the x-axis, indicating that progress each week is slower and not in accordance with the planned schedule. An accelerated duration curve line sloping closer to the y-axis indicates greater progress each week and the accelerated duration curve line is not much different from the plan curve line. If an S-curve is above another S-curve, it indicates a greater volume of work completed until the end of the project, which can accelerate the project completion duration.

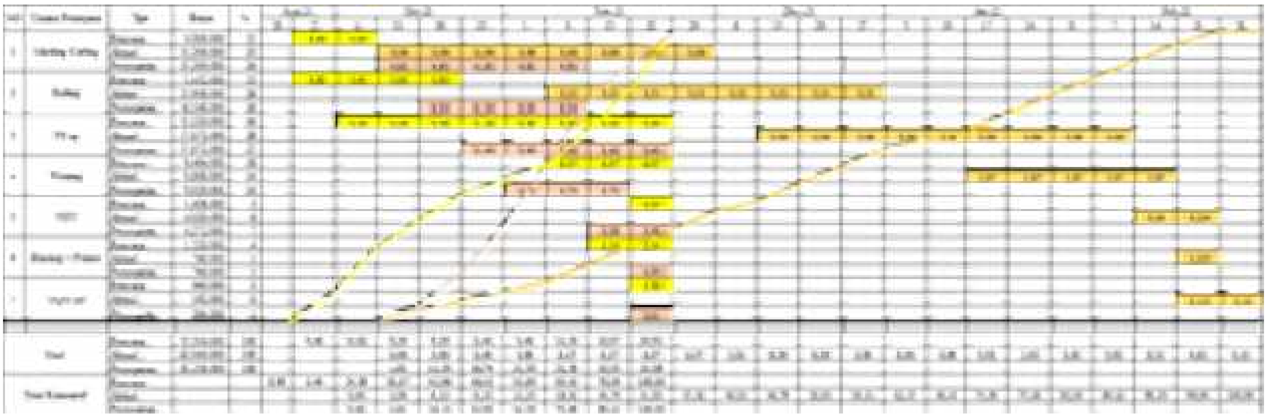

Figure 4. S curve of Pressure Vessel project

IV. CONCLUSION

Based on the results of the analysis that has been carried out and discussed, the following conclusions are obtained:

1. From the analysis obtained using the PDM method, the entire fabrication process is a critical activity that can be accelerated.
2. From the calculation results, the optimal time and cost is obtained with an alternative of adding 75% of the manpower, the resulting duration is the same as the plan duration of 96 days. In the acceleration duration there is a difference of 75 days from the actual duration. The cost incurred from the alternative of adding 75% of the manpower is Rp.161,386,836, - a 56% decrease from the actual duration cost of Rp. 286,961,745,-
3. Comparison of Pressure Vessel progress using the S-curve obtained the results of the actual duration curve line sloping closer to the x-axis shows the development of each week is not in accordance with the plan schedule. The curve line on the accelerated duration schedule is more sloping close to the y-axis indicating the development of each week is greater and the slope of the accelerated duration curve line is not much different from the plan curve line indicating the progress of work progress each week is greater.

V. ACKNOWLEDGMENT

The author would like to thank all those who have helped and supported the completion of this paper. this research. Hopefully this research can be useful and a blessing for all parties.

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