

# Risk Analysis and Mitigation in the Procurement Process of Overhaul Services

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**Abstract**— PT. XYZ is one of subsidiaries of state-owned company which has core business in Power Generation and Operation & Maintenance (O&M) Services for power plants. There are a lot of challenges that should be faced by PT. XYZ as a maintenance unit to achieve the on cost, on time and on quality target. Therefore, we need an analysis and risk mitigation in the procurement process of overhaul routine services to assist companies in dealing with potential risks. Risk identification is carried out using literature studies and expert panels. After that, the risk will be analyzed using the Analytic Network Process and House of Risk methods. The use of the ANP method in this study is as additional tools to support the HOR method because in this study it is possible to have a relationship between risk events and risk agents. This relationship is not captured by the HOR method because the HOR method only considers the relationship between the risk event and the risk agent. The results shows that there are 23 risk events that caused by 37 risk agents. Based on ARP result, there are 2 main mitigation efforts that can be done by the company which are increase the coordination between stakeholder and implemented the time-based contract for overhaul routine services. These efforts hopefully could help the company to reduce the probability of risk agents so the overhaul will not be affected.

**Keywords**— Risk Management, Procurement, Analytic Network Process (ANP), House of Risk (HOR).

## I. INTRODUCTION

PT. XYZ as a maintenance unit faces many challenges in order to reach on cost, on time and on quality in their overhaul process. Those challenges such as the unpredictable changes of overhaul schedule, the procurement process that sometimes takes a long time also the scope addition of overhaul that consistantly increase. While PT. XYZ has a performance assessment and the failure to reach these goals will give the big impact to the company performance score. All the challenges could be the risk for the company. Risk as an event with the ability to influence (inhibit, increase or cause doubt about) mission, strategy, projects, routine operations, objectives, core processes, main dependencies and / or deliver expectations of stakeholders [1]. Supply chain department has an important role to prevent lateness and support PT. XYZ reach their goal. The process that usually take long time are the procurement for 5 kinds of routine services (coating rubber, coating ceramic, eddy current, cleaning condenser and retubing boiler) because it should be done by an auction. Meanwhile it is needed more than 20 times for each services as shown in Figure 1. It can increase the probability of lateness because the supply chain department needs to keep repeated the auction. Not to mention the risk if the overhaul schedule suddenly changed.

## Routine Services Frequency on 2018

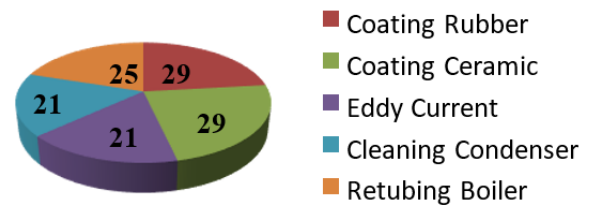


Figure 1. Frequency of Routine Services on 2018.

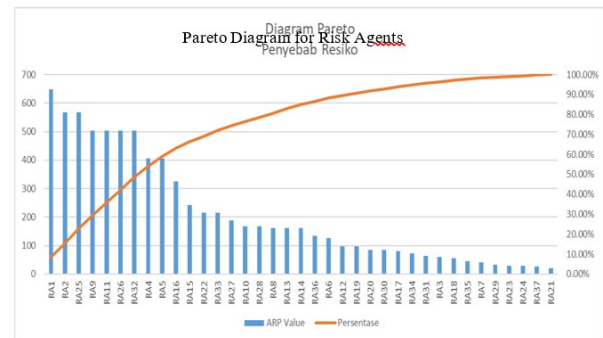


Figure 2. Pareto Diagram

Therefore it is needed to do a risk management to analyze risk that might be the obstacle for supply chain department and plan a mitigation action to prevent the occurrence of those risks. Risk management is an application of general management that tries to identify, measure and handle the causes and consequences of uncertainty in an organization [2]. Risk analysis and mitigation will be done by using ANP and HOR methods. From this analysis and preventive actions, hopefully PT. XYZ could reduce the probability of lateness and reach their goals.

## II. METHOD

There are two methods that are used in this study, ANP and HOR. ANP is used to analyze the relationship not only between risk agent and risk event but also between risk agent and between risk event. This relationship doesn't defined in HOR method. While HOR is used to identify the risk agents which will be prioritized to be maintained and be given the mitigation plans. Risk analysis started by identification, analysis, evaluation and plan the preventive action as mitigation. The identification process is needed to identify the business process of procurement process therefore we can clearly identify the risk events and risk agents that might be occur along the process. The business process of supply chain department are identified in Table 1.

Table 1.  
Supply chain business process at PT. XYZ

<b>Business process for Resource Planning Division</b>
Make a Contract of Agreement between the Maintenance Unit and the Generating Unit to be overhauled Make a Term of Reference (TOR)
Make Estimated Engineering Prices (HPE)
Make a Work Plan and Terms document (RKS)
Make a Purchase Requisition (PR)
<b>Business process for Procurement Division</b>
Make Owner Estimated Price (HPS)
Supplier selection
Bid submission (sent from company to supplier company)
Opening and evaluating bids (offers received from supplier companies)
Negotiation
Determination and appointment of winners
Contract signing
Overhaul process (levering period)
Making Work Completion report (BA)
Billing and payment

Table 2.  
ARP Rank

Risk Agents	Code	ARP	ARP Rank	Risk Agents	Code	ARP	ARP Rank
Requests from users regarding job specifications are incomplete or unclear	RA1	648	1	The billing terms document is incomplete	RA36	135	20
Pricing information is not available, either in history data or in the market	RA2	567	2	The corporate network system is down	RA6	126	21
The selected supplier is incompetent	RA25	567	3	Supplier neglects in preparing the required documents	RA12	96	22
Lack of supplier knowledge	RA9	504	4	Late approval by management team	RA19	96	23
Supplier does not understand the requirements stated in the auction's document	RA11	504	5	The corporate network system is down	RA20	84	24
Calculation error in making estimation of area	RA26	504	6	Uncertain internal lead time of the overhaul	RA30	84	25
Addition of scope of work	RA32	504	7	Did not reach a deal price	RA17	81	26
Sudden request for service work so it takes time to make its supporting documents	RA4	405	8	PIC is late in processing BA	RA34	72	27
The basic document from the Generating Unit (UP) as the user is delayed	RA5	405	9	Supplier's lack of personnel in doing the services	RA31	63	28
The offering price is over-budget	RA16	324	10	Inaccuracy from related PICs when making purchase requisition (human error)	RA3	60	29
None of the bidders met the administrative, technical or price requirements	RA15	243	11	PIC forgot to make a letter of determination & letter of appointment for the winner	RA18	56	30
Mistaken in bid evaluation process	RA22	216	12	suppliers are uncooperative and responsive in completing payment documents according to company standards	RA35	45	31
Incomplete BA requirement documents	RA33	216	13	Bulletin boards is not strategic	RA7	42	32
There is an area that is not included in the scope of work but suddenly must be done immediately	RA27	189	14	Material is hard to find	RA29	32	33
Lack of coordination between PICs and auction participants	RA10	168	15	The PIC was late in drafting and reviewing the contract	RA23	28	34
Government policies that affect material prices	RA28	168	16	Management who is in charged to sign contracts is not present / late for signing	RA24	28	35
Supplier is a new party in the service that being auctioned	RA8	162	17	The corporate network system is down	RA37	27	36
Supplier did a fraud	RA13	162	18	Bulletin boards is not strategic	RA21	21	37
PICs are not careful in evaluating	RA14	162	19				

Identification is also needed to define how significant the impact caused by the risk events if it happened. It is called the severity scale. The identification process is done by expert panel with senior supervisor of resource planning division and senior supervisor of procurement division and also questionnaire. There are 23 risk events that are caused by 37 risk agents. Each risk events have different scale of

severity. After that, we also need to identify the likelihood of occurrence. The likelihood of occurrence can be interpreted as how often the probability of the risk agent occurs. The higher the scale the more likely it occurs. Last thing that is needed to identified is the correlation scale between risk agents and risk events. This correlation scale shows how big the relationship between risk events and risk agents. The

Table 3.  
Preventive Actions

Risk Agents	Code	Preventive Actions
Requests from users regarding job specifications are incomplete or unclear	RA1	Improve coordination with UP as the user before the implementation of overhaul schedule (PA1)
Pricing information is not available, either in history data or in the market	RA2	Make a Request Letter to Supplier regarding to Price Information (PA2) Searching for history data from other units (PA3) Monitoring prices regularly (PA4)
The selected supplier is incompetent	RA25	Make a list of service suppliers that has a good competency assessment (PA5) Tightening the experience in similar work criteria as a requirement for registering auction participants (PA6) Implementing a time-based contract for routine service overhaul (PA7) State a guarantee clause in the contract for the results of services (PA8) Improve coordination between PICs to suppliers (PA9)
Lack of supplier knowledge	RA9	Involving the user and engineering in the Aanwijzing process (PA10) Creating a mailing list system as a communication media between PIC and auction participants (PA11)
Supplier does not understand the requirements stated in the auction's document	RA11	Improve coordination between PICs to suppliers (PA9) Creating a mailing list system as a communication media between PIC and auction participants (PA11)
Calculation error in making estimation of area	RA26	Improve coordination with UP as the user before the implementation of overhaul schedule (PA1) Monitoring the same service work based on history to find out the estimated area that is usually done (PA12)
<b>Addition of scope of work</b>	<b>RA32</b>	<b>Implementing a time-based contract for routine service overhaul (PA7)</b>
Sudden request for service work so it takes time to make its supporting documents	RA4	Implementing a time-based contract for routine service overhaul (PA7)
The basic document from the Generating Unit (UP) as the user is delayed	RA5	Improve coordination with UP as the user before the implementation of overhaul schedule (PA1)
<b>The offering price is over-budget</b>	<b>RA16</b>	<b>Implementing a time-based contract for routine service overhaul (PA7)</b>
None of the bidders met the administrative, technical or price requirements	RA15	Improve coordination between PICs to suppliers (PA9) Creating a mailing list system as a communication media between PIC and auction participants (PA11)
Mistaken in bid evaluation process	RA22	Monitoring the same service work based on history to find out the estimated area that is usually done (PA12) Improve coordination between PICs to suppliers (PA9)
Incomplete BA requirement documents	RA33	Creating a mailing list system as a communication media between PIC and auction participants (PA11)
There is an area that is not included in the scope of work but suddenly must be done immediately	RA27	Improve coordination with UP as the user before the implementation of overhaul schedule (PA1) Implementing a time-based contract for routine service overhaul (PA7)
Lack of coordination between PICs and auction participants	RA10	Improve coordination between PICs to suppliers (PA9) Creating a mailing list system as a communication media between PIC and auction participants (PA11)
Government policies that affect material prices	RA28	Implementing a time-based contract for routine service overhaul (PA7)
Supplier is a new party in the service that being auctioned	RA8	Improve coordination between PICs to suppliers (PA9)

higher the correlation scale, it can be concluded that the relationship between risk events and risk agents is greater, meaning that if the risk agent occurs, then the likelihood of the risk event related to that risk agent will also occur.

A. Analytic Network Process (ANP)

The Analytic Network Process (ANP) is a generalization of the Analytic Hierarchy Process (AHP), by considering the dependence between the elements of the hierarchy. Many decision problems cannot be structured hierarchically because they involve the interaction and dependence of higher-level elements in a hierarchy on lower-level elements. Therefore, ANP is represented by a network, rather than a hierarchy [3]. In this study, ANP is used to analyze the relationship between risk agents and risk events. Based on identification process, there are 23 risk events and 37 risk agents. The experts need to fill the questionnaire to identify which one that has a relationship among them, both for risk

events and risk agents. The one that has relationship to another will be analyzed by using Super Decision 2.1.

First, we need to build the ANP model both for risk agents and risk events. These models consider the relationship from previous step. One example of the relationship that occurs between risk events is the risk of "Delay in completion of routine services (RE20)" will affect the risk of "Delay in making work completion report (RE21)" and the risk of "Delay in making verified payment document (RE23)". While one example of the relationship that occurs between the risk agent is "Lack of coordination between PICs to auction participants (RA10)" will affect the risk agents "Lack of supplier knowledge (RA9)" and "Suppliers do not understand the requirements stated in auction documents (RA11)".

Second, calculate the weight for risk agents and risk events using pairwise comparison in Super Decision 2.1. After

Table 4.  
Result of Calculation of Effectiveness Level, Difficulty Level and Difficulty Effectiveness Ratio

Criteria	PA1	PA2	PA3	PA4	PA5	PA6	PA7	PA8	PA9	PA10	PA11	PA12
Total effectiveness of preventive action (TEk)	15714	5103	5103	5103	5103	5103	19413	5103	16173	4536	5643	1944
Level of difficulty (Dk)	4	3	4	4	4	3	4	3	3	4	4	5
Effectiveness ratio of the difficulty level preventive action (ETDk).	3928.5	1701	1275.8	1275.8	1275.8	1701	4853	1701	5391	1134	1410.8	388.8
Ranking of preventive actions	3	4	6	6	6	4	2	4	1	7	5	8

Table 5.  
Implications for the company

No	Preventive Actions	Code	Implications for the company
1	Improve coordination with UP as the user before the implementation of overhaul schedule	PA1	Minimize the occurrence of errors in the process of making service specifications in the Term of Reference (ToR) so it can also minimize the mistake in the supplier selection process Accelerate the duration of the procurement because there is no need to review or change the specifications in the procurement document
2	Make a Request Letter to Supplier regarding to Price Information	PA2	Minimize errors in making HPE and HPS that are used as a reference for the price negotiation process so it will be easier to reach an agreement price Minimize the risk of auction failure
3	Searching for history data from other units	PA3	Minimize errors in making HPE and HPS that are used as a reference for the price negotiation process so it will be easier to reach an agreement price Minimize the risk of auction failure Get a reasonable price estimate
4	Monitoring prices regularly	PA4	The resource planning division will always be aware of the latest price of overhaul services so it can minimize errors in making HPE and HPS Minimize the risk of auction failure
5	Make a list of service suppliers that has a good competency assessment	PA5	1. Availability of a List of Selected Suppliers (DPT) for routine services of overhaul so the procurement process can be carried out by a limited auction method 2. Avoid the risk of choosing an incompetent supplier 3. Maintaining the quality of service so that it can help the achievement of targets on quality in the implementation of overhauls
6	Tightening the experience in similar work criteria as a requirement for registering auction participants	PA6	Avoid the risk of choosing an incompetent supplier Maintaining the quality of service so that it can help the achievement of targets on quality in the implementation of overhauls
7	Implementing a time-based contract for routine service overhaul	PA7	Accelerate the duration of the service procurement process because the auction process is only done once for a certain period (for example 1 year) so if there is a need for the service within the contract period, a Delivery Order (DO) can be made immediately without reauction Avoid the risk of unstable work prices throughout the contract period because the time-based contract are binding unit prices throughout the contract period Maintaining the quality of service work so that it can help the achievement of targets on quality in the implementation of overhauls As a mitigation effort if there is a sudden change in overhaul schedule
8	State a guarantee clause in the contract for the results of services	PA8	The company gets a guarantee of repairs if there are jobs whose under quality without having to spend additional funds
9	Improve coordination between PICs to suppliers	PA9	Minimize errors in the procurement process due to supplier ignorance so that auction process can run well Minimize the risk of auction failure
10	Involving the user and engineering in the Aanwijzing process	PA10	Minimize errors in the procurement process due to supplier ignorance so that auction process can run well Minimize the risk of auction failure
11	Creating a mailing list system as a communication media between PIC and auction participants	PA11	Minimize errors in the procurement process due to supplier ignorance so that auction process can run well Minimize the risk of auction failure
15	Monitoring the same service work based on history to find out the estimated area that is usually done	PA12	Minimize the occurrence of error in the process of area estimation so it can also minimize the risk of overbudget Minimize the risk of the sudden appearance of an additional area so that the overhaul process can continue according to the planned schedule and support the achievement of the target on time overhaul

inputting into the Super Decision software and calculated using the pairwise comparison menu, the weight for each risk events and risk agents will indicate which one has the highest relationship among the others. For example, risk event “Mistaken in determining the HPE and HPS (RE2)” will trigger other risk events that are: “There are no bidders who

pass the selection (RE11)” with a weight of 0.36628, “A failed auction (RE12)” with a weight of 0.30726, “Delay in making a letter of determination & appointment of winners (RE13)” with a weight of 0.09823, “Delay in signing contracts (RE16)” with a weight of 0.12768, “Mark-up of supporting materials for services (RE19)” with a weight of

0.04131 and “Delay in making work completion report (RE21)” with a weight of 0.05924. Therefore we can conclude that the risk event “No bidders who pass the selection (RE11)” have the highest weight compared to other triggered risk events, so it can be concluded that if a risk event “Mistaken in setting HPE and HPS (RE2)” occurs, it is most likely a risk event RE11 will also occur.

Third, we need to calculate the new severity scale for risk events and new likelihood of occurrence for risk agents. The new severity scale for risk events is calculated as below:

New severity scale of RE2 = Old severity scale of RE2 + (Old severity scale of RE11 x weight of RE11) + (Old severity scale of RE12 x weight of RE12 + ... + (Old severity scale of RE21 x weight of RE21) (1)

While the new likelihood of occurrence scale for risk agents is calculated as below:

New likelihood scale of RA11 = Old likelihood scale of RA11 + (Old likelihood scale of RA12 x weight of RA12) + (Old likelihood scale of RA15 x weight of RA15) + ... + (Old likelihood scale of RA25 x weight of RA25) (2)

#### B. House of Risk (HOR)

The second method used in the analysis of this study is the House of Risk (HOR) method. The HOQ method is one part of the Quality Function Development (QFD) method that will be used to design risk mitigation strategies. The HOR method is carried out in 2 phases where the first phase is used to make ranking of each risk agent (cause of risk) based on the Aggregate Risk Potential (ARP) value and the second phase is used to facilitate management in prioritizing the risk management that has been identified and calculated the level of risk in the first phase [4].

First, we need to calculate the Aggregate Risk Potential (ARP). Calculations using the ANP method in the previous stage have given new severity and new likelihood of occurrence values for each risk event and risk agent. This value has taken into consideration the interrelationships between related components. The output of the ANP method will be used as input to the HOR method to calculate the ARP value which will be used as a benchmark value to manage the risk agents. The ARP value is obtained from the multiplication result of the severity value, the likelihood of occurrence value, and the correlation value.

Second, evaluate the output of ARP to determine which risk agents will be prioritized for the mitigation plan to be made in advance. ARP calculation results will be done by ranking the ARP value from the largest value to the smallest value so that the sequence of risk agent is obtained which has the highest to lowest priority index. After obtaining this ranking, then the ARP value will be mapped by using the Pareto diagram. The use of Pareto diagrams is to assist the process of selecting a number of causes of risk that will be prioritized. Risk agents that have the highest ARP value must be prioritized for further analysis at the HOR stage 2 to be given the preventive actions.

Lastly, create the preventive action as a mitigation for the risk agents. Mitigation strategy planning is done by interviewing the senior supervisor of procurement division and senior supervisor of quality assurance division. The next step that must be done is to calculate the correlation value between the preventive actions with the risk agents. After

determining the correlation, the effectiveness of each preventive actions will be calculated. Calculation of the level of effectiveness aims to measure how much action taken by the company will affect in reducing the frequency of risk agents. The effectiveness can be calculated by using this formula:

**RUMUS(3)**

In addition to calculating the level of effectiveness, it is necessary to determine the level of difficulty (Dk) of each preventive actions. Determination of the level of difficulty is also done by interviewing the senior supervisor of procurement division and senior supervisor of quality assurance division by using 3 measurement scales which are scale 3 (low difficulty level), scale 4 (moderate difficulty level), and scale 5 (high difficulty level). After getting the value of the level of effectiveness and difficulty level, the effectiveness of the difficulty of an action (ETDk) will then be calculated using the following formula:

**RUMUS(4)**

### III. RESULT AND DISCUSSION

After identify the business process of supply chain department, it can be found that there are 5 processes in resource planning division and 10 processes in purchasing division. 15 main processes has its own risks. Those risks can be classified as 23 risk events that caused by 37 risk agents. All these risk agents can't be solved at the same time. Therefore, we need to prioritize them first.

The first step is using ANP methods. This calculation shows the weight for every risk events and risk agents by considering their interrelationship. From ANP, we also get the new value for severity and occurrence. For example, at the first time the output from questionnaire state that the severity value for RE2 before considering interrelationship is at the scale 5 whereas after considering the interrelationship, the severity scale changed to 9. This shows that there is an influence on the severity value of RE2 where once this risk event was considered to have a small impact but the relationship between risk events causes the impact of this risk to be large. This impact is large because it gets a large proportion of the risks triggered by RE2. This interrelationship consideration hopefully could make it easier for the company to know which risks must be prioritized first to be mitigated because if the risk is successfully mitigated, then the risk triggered by the risk can also be automatically minimized. It also happens to the value of likelihood for risk agents. Before considering the interrelationship, RA11 has a likelihood of occurrence at the scale 3 whereas after considering the interrelationship, the likelihood of occurrence changes to 7. This shows that there is an influence on the likelihood of occurrence of RA11 where previously this risk agent was considered to have a small likelihood of occurrence, but there was an interrelationship between the risk agents indicates the likelihood of occurrence from the risk agent (RA11) being greater so that it is more likely to occur. This value becomes large because it is obtained from the contribution of a large proportion of the other risk agent that is triggered by RA11.

This interrelationship consideration hopefully could make it easier for the company to which risk agents that must be prioritized first to be mitigated because if it can minimize the possibility of other risk agents.

The second step is analysis process using HOR. The new value of severity and likelihood of occurrence from the output of ANP will be used as the input to calculate the value of ARP. The ARP value is obtained from the multiplication between the severity value, the likelihood of occurrence, and the correlation value. This ARP value will be ranked to find which risk agent that has the highest score. The result of ARP calculation shown in the Table 2.

All these risk agents will be mapped by using Pareto diagrams as shown in Figure 2. Pareto diagram has the principle that 80:20 which means 20% of the risk agents can cause 80% of risk events. There are 17 risk agents that will be prioritized to be given preventive actions as shown in Table 3. The next step is calculating ETDk. It shows the ranking of preventive actions sorted by the ratio of the effectiveness of the difficulty level of each preventive action.

Out of 12 mitigation action plans in Table 4, the highest ranking is in the 9th mitigation measure which is to improve coordination between PICs to suppliers. PIC in this case can be from the procurement staff as well as from the user to ensure that suppliers who participate in the auction really understand the auction information and the service that being auctioned. The second mitigation plan is TM7 (implementing a time-based contract for overhaul routine service). This contract is a type of unit price contract that is binding for a certain period in accordance with the provisions at the beginning of the auction. With the implementation of this contract, the supplier who wins the auction will be bound by the unit price so no matter how much the surface area that should be done will have a fixed price for the certain contract period. In addition, the company will also get a guarantee of readiness from the supplier to be able to do the services at any time so that it can anticipate the condition of the overhaul schedule that frequently and suddenly changed.

These preventive actions will give positive implication to the company and will help them reach their goals if it is well-implemented and well-controlled. The implications from 12 preventive actions are shown on the Table 5.

#### IV. CONCLUSION

In this study, the definition of business process and scope should be clear to help the stakeholder identify the risk events that might be the obstacle during the process. There are 23 risk events that have the possibility to arise in the process of service procurement at PT. XYZ. 23 of these risk events are caused by 37 different risk agents. ANP is used to identify the new value for severity in risk event and likelihood of occurrence in risk agent by considering interrelationship one to the others. It is proven that by considering the interrelationship, the value of severity and likelihood of occurrence increase compare to the old one. ANP has a function to capture the interrelationship between risk agents and between risk events that is not captured in HOR method.

Second analysis is done by using HOR. Risk analysis using HOR is calculated by multiplying the new value of severity, new value of likelihood of occurrence and relationship value between risk event and risk agent. The result shown that out of 23 risk events, there are 17 risk events which has the highest impact value after considering its relationship among others. This risk event can have a significant impact on company goals and can lead to deviation of the achievement target of > 50%. Therefore it must be analyzed the causes of the risk for mitigation efforts. Based on the ARP calculation of risk agents, obtained 17 risk causes that have an ARP value above 160 which is a high risk category so that the formulation of mitigation efforts is prioritized for these 17 causes of risk.

Based on the calculation of the difficulty effectiveness ratio of each preventive action, there are 2 preventive actions with the highest difficulty effectiveness ratio which are Improve coordination between PICs to suppliers (PA9) and Implementing a time-based contract for routine service overhaul (PA7). Both of these mitigation actions can be done to minimize the opportunities of risk agents so as to minimize the opportunities for risk events that can have an impact on the procurement of overhaul routine services.

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