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Maintenance Management Plan of Heavy Machinery

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Abstract- Heavy machinery is a major resource for a highway department. The goal of this study is to develop a three-wheel roller and truck maintenance plan for reducing the maintenance cost. This plan is designed to add values to maintenance procedures and reduce the risks and exposures to loss the department is currently experiencing. Therefore, not only is the need improved maintenance performance addressed, but also worker and property exposures are controlled as well. Breakdown and preventive maintenance plans were used for highway department. Moreover, compute for standby machine when an online machine fails is another way to maintain service.

Indexed Terms - Heavy machinery, maintenance cost, risks and exposures, Breakdown and preventive maintenance plans, maintain service.

I. INTRODUCTION

Maintenance is a huge profit center when it is done correctly. It can make as much money for an industrial company as the operations group tasked to make the company’s products. But you have to do maintenance in a certain way. There is a best practice way to do maintenance planning and scheduling that guides companies and their maintenance crews to world class performance. Maintenance Planning and Scheduling is a key component in delivering maintenance services effectively and efficiently.

After leaving the maintenance manager roll in an industrial process chemical manufacturer in 2005 I started presenting maintenance planning and scheduling training courses around Australia and Asia. The course I present is designed and built from a business owner’s point of view. Unlike other maintenance planning and scheduling trainers who teach you the mechanics of maintenance planning and scheduling, I also teach you how to make vast sums money from maintenance through its proper preparation, organization and delivery.

Maintenance done as explained in this book is not a cost. Great maintenance is a rainmaker of moneys now lost to waste, catastrophe and misunderstanding. Maintenance planning and scheduling for reliability helps to double operating profit in the average industrial company.

Doing maintenance planning and scheduling is important. But the incredible difference to a company comes from what is done when you do the planning. The secret knows how to plan and prepare maintenance work so that it creates world class reliability. With world class reliability comes magnificent operational performance, and more operating profits than you can imagine. World class maintenance practices can double your margin and sustain it thereafter.

II. MAINTENACE

A. Maintenance Management and Control

The management and control of maintenance activities are equally important to performing maintenance. Maintenance management may be described as the function of providing policy guidance for maintenance activities, in addition to exercising technical and management control of maintenance programs 1, 2. Generally, as the size of the maintenance activity and group increases, the need for better management and control become essential.

(i) Maintenance Department Functions and Organization

A maintenance department is expected to perform a wide range of functions including:

- Planning and repairing equipment/facilities to acceptable standards.
- Performing preventive maintenance; more specifically, developing and implementing a regularly scheduled work program for the purpose of maintaining satisfactory

equipment/facility operation as well as preventing major problems.

- Preparing realistic budgets that detail maintenance personnel and material need.
- Managing inventory to ensure that parts/materials necessary to conduct maintenance tasks are readily available
- Keeping records on equipment, services, etc.
- Developing effective approaches to monitor the activities of maintenance staff.
- Developing effective techniques for keeping operations personnel, upper-level management, and other concerned groups aware of maintenance activities • Training maintenance staff and other concerned individuals to improve their skills and perform effectively.
- Reviewing plans for new facilities, installation of new equipment, etc.
- Implementing methods to improve workplace safety and developing safety education-related programs for maintenance staff.
- Developing contract specifications and inspecting work performed by contractors to ensure compliance with contractual requirements.

Generally, centralized maintenance serves well in small- and medium-sized enterprises housed in one structure, or service buildings located in an immediate geographic area. Some of the benefits and drawbacks of centralized maintenance are as follows:

(ii) Benefits

- More efficient compared to decentralized maintenance.
- Fewer maintenance personnel required.
- More effective line supervision.
- Greater use of special equipment and specialized maintenance persons.
- Permits procurement of more modern facilities.
- Generally, allows more effective on-the-job training.

(iii) Drawbacks

- Requires more time getting to and from the work area or job.
- No one individual becomes totally familiar with complex hardware or equipment.
- More difficult supervision because of remoteness of maintenance site from the centralized headquarters.
- Higher transportation cost due to remote maintenance work.

B. Preventive Maintenance

Preventive maintenance (PM) is an important component of a maintenance activity. Within a maintenance organization it usually accounts for a major proportion of the total maintenance effort. PM may be described as the care and servicing by individuals involved with maintenance to keep equipment/facilities in satisfactory operational state by providing for systematic inspection, detection, and correction of incipient failures either prior to their occurrence or prior to their development into major failure.1 Some of the main objectives of PM are to: enhance capital equipment productive life, reduce critical equipment breakdowns, allow better planning and scheduling of needed maintenance work, minimize production losses due to equipment failures, and promote health and safety of maintenance personnel.

(i) Preventive Maintenance Elements, Plant Characteristics in Need of a PM

There are seven elements of PM as shown in Figure 1.

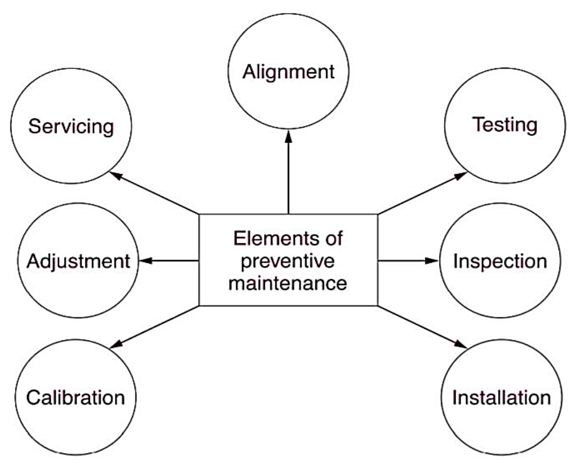

Figure 1. Elements of preventive maintenance.

Each element is discussed below: 1. Alignment

2. Servicing
3. Testing
4. Inspection
5. Installation
6. Calibration
7. Adjusting

(ii) Important Steps for Establishing a PM Program

To develop an effective PM program, the availability of a number of items is necessary. Some of those items include accurate historical records of equipment, manufacturer's recommendations, skilled personnel, past data from similar equipment, service manuals, unique identification of all equipment, appropriate test instruments and tools, management support and user cooperation, failure information by problem/cause/ action, consumables and replaceable components/parts, and clearly written instructions with a checklist to be signed off.

There are a number of steps involved in developing a PM program. Figure 2 presents six steps for establishing a highly effective PM program in a short period. Each step is discussed below.

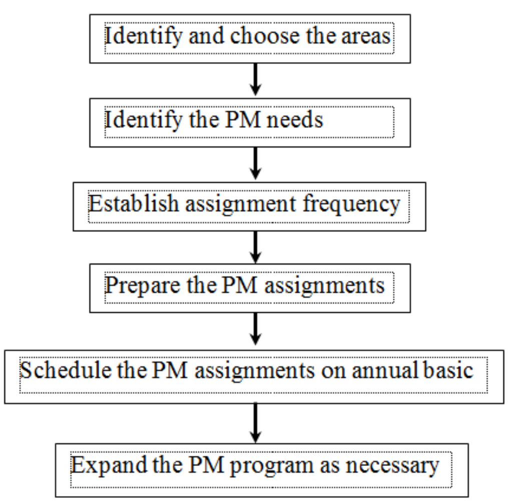

Figure 2. Six steps for developing a PM program

C. Corrective Maintenance

Although every effort is made to make engineering systems as reliable as possible through design, preventive maintenance, and so on, from time to time they do fail. Consequently, they are repaired to their operational state. Thus, repair or corrective maintenance is an important component of maintenance activity. Corrective maintenance may be defined as the remedial action carried out due to failure or deficiencies discovered during preventive maintenance, to repair an equipment/item to its operational state.

Usually, corrective maintenance is an unscheduled maintenance action, basically composed of unpredictable maintenance needs that cannot be preplanned or programmed on the basis of occurrence at a particular time. The action requires urgent attention that must be added, integrated with, or substituted for previously scheduled work items. This incorporates compliance with "prompt action" field changes, rectification of deficiencies found during equipment/item operation, and performance of repair actions due to incidents or accidents. A substantial part of overall maintenance effort is devoted to corrective maintenance, and over the years many individuals have contributed to the area of corrective maintenance. This chapter presents some important aspects of corrective maintenance.

(i) Corrective Maintenance Types

Corrective maintenance may be classified into five major categories as shown in Figure 3. These are: fail-repair, salvage, rebuild, overhaul, and servicing. These categories are described below.

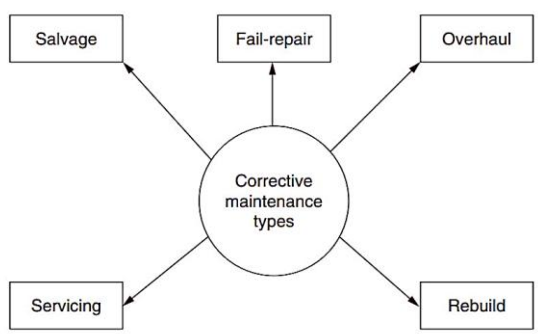

Figure 3. Types of corrective maintenance

(ii) Corrective Maintenance Steps

Different authors have laid down different sequential steps for performing corrective maintenance. For example, Reference 2 presents nine steps (as applicable): localize, isolate, adjust, disassemble, repair, interchange, reassemble, align, and checkout. Reference 3 presents seven steps (as applicable): localization, isolation, disassembly, interchange, reassemble, alignment, and checkout.

For our purpose, it is assumed that corrective maintenance is composed of five major sequential steps, as shown in Figure 4.

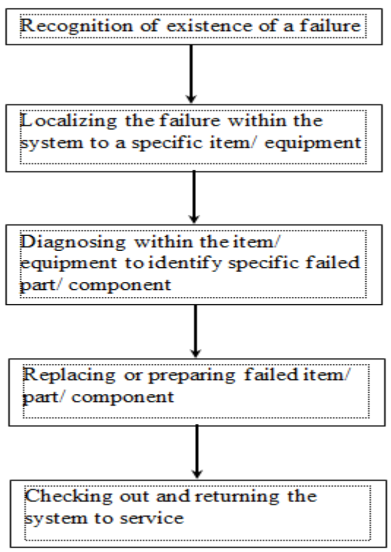

Figure 4. Corrective Maintenance Sequential Steps

III. MAINTENCE AND REPLACEMENT

A. Short-Term Maintenance Policies

For an existing from with an internal maintenance friction many of the critical factors that determine the inherent reliability of the operation system have been decided in the design phase. It is still possible, however to take a number of steps in the short run that can keep the process in good working conditions. They may include the following.

- Training machined operations.
- Training maintenance-crew workers.
- Making use of decoupling i.e., work in process and finished goods inventories, to allow limited operation during the maintenance.
- Providing adequate inventory of space parts to reduces repair time.
- Using preventive maintenance to reduce the frequency of breakdowns.
- Using overtime to make up for lost production due to repairs.
- Using group rather than individual replacement for low valued items.

These alternatives can be used in different combinations to formulate satisfactory short-term maintenance policies.

(i) Preventive Versus Breakdown

Management may choose to a allow a machine to operate until it breaks down after a run time T. the maintenance crew then proceeds to fix the machines, taking an average repair time equal to T_r, the mean value of a repair-time distribution f (T). After repair the machine runs until the next breakdown, and so on. This policy is known as the breakdown maintenance and shown in Figure 3.1 (a).

As alternative approach is to operate the machine for a certain period T_p and then inspect it to assess its operating status and replace of necessary any critical components for which a breakdown in imminent. The average time for performing the preventive maintenance is T_m, a mean value of a preventive maintenance time distribution g(T). The fixed time T_p between successive inspections is called the preventive- maintenance period.

The sum of T_m and T_p is the complete preventive-maintenance cycle. Occasionally, the machine may breakdown between the regular inspectors, in which case the maintenance crew will repair it with the same average repair time T_r. this maintenance policy is known as preventive maintenance and shown in Figure 3.1 (b).

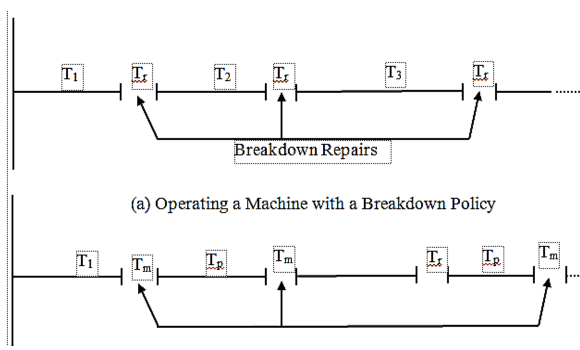

Figure 5. Alternative Short-Term Maintenance Policies

If the expected cost of breakdown per period without preventive maintenance is greater than the expected cost of breakdown with preventive maintenances, prevent is the best policy.

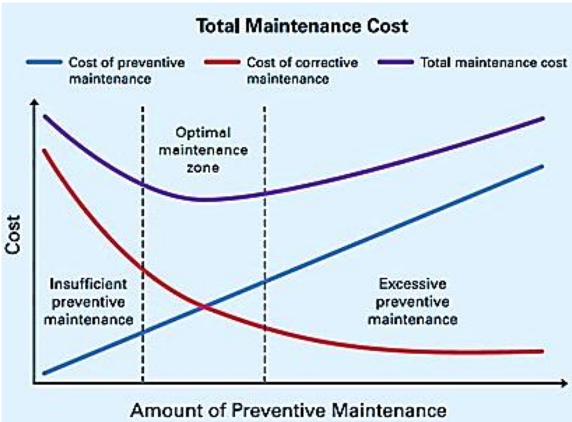

Figure 6. Balance of Cost Defining an Optimal Preventive Maintenance

B. Maintenance and Maintenance Engineering Objectives

Even though maintenance engineering and maintenance have the same end objective or goal, the environments under which they operate differ significantly. More specifically, maintenance engineering is an analytical function as well as it is deliberate and methodical. In contrast, maintenance is a function that must be performed under normally adverse circumstances and stress, and its main objective is to rapidly restore the equipment to its operational readiness state using available resources.

IV.MAINTENANCE CALCULATION

A.General Information

Plan of break-down maintenance for three-wheel roller

Total number of three-wheels roller =1,000 machines

For breakdown maintenance

The cost of the overhaul and repair = 1,400,000 kyats

For preventive maintenance

The cost of the overhaul = 300,000 kyats

Individual repairs cost = 150,000 kyats

Information inputs may pertain to the history of Three-wheel Rollers in terms of number of machines and number of hours between major breakdowns is shown in Table I.

Table I. Breakdown Data of Three - Wheels Roller

Number of Three-wheels Roller	Number of Hours Between Major Breakdown
10	1000-2000
40	2000-3000
180	3000-4000
240	4000-5000
270	5000-6000
140	6000-7000
100	7000-8000
10	8000-9000
10	9000-10000

Number of three wheel rollers and probability of failures are calculated in Table II

Table II. Calculated Results for Probability of Failure

Number of Three-Wheel Roller	Probability of Failure P(I)	Number of Hours Between Major Breakdown
10	0.01	1000-2000
40	0.04	2000-3000
180	0.18	3000-4000
240	0.24	4000-5000
270	0.27	5000-6000
140	0.14	6000-7000
100	0.1	7000-8000
10	0.01	8000-9000
10	0.01	9000-10000

B. Calculation of Breakdown Maintenance Policy

All breakdowns occur at the end of each interval.

Average number of hours between breakdowns

L_{avg}= [(2 × 0.01) + (3 × 0.04) + (4 × 0.18) + (5 × 0.24) + (6 × (0.27) + (7 × 0.14) + (8 × 0.1) + (9 × 0.01) + (10 × 0.01)] × 10^3 = 5,650 hrs

Number of breakdowns for each 1000 hours

10000/5650 × 1000= 1,769.9115 machines

Total breakdown maintenance cost per 1000 hours

= 1,769.9115 × 1,400,000

= 2,477,876,100 kyats

C. Calculation of Preventive Maintenance Policy

Preventive maintenance policy on scheduled basis.

Total preventive Maintenance cost (TPM) = total preventive cost (TBC) + total breakdown cost (TPC)

D. Calculation of Standby Machine for Three-Wheels Roller

Plan of stand by machine for three - wheels Rollers calculation for probability of failures.

Poisson Distribution

$$P_n = \frac{e^{-\lambda}\lambda^n}{n!}$$

λ= average of machines undergo repairs = 3 machines

e = 2.7183

Stand by cost= 20,000 kyats/day

Loss in work and service= 100,000kyats/ machine/day

Conditions get serious when six or more machines are out of operation at once.

So, addition loss = 200,000 kyats

Minimum total cost = 112,960 kyats

Five standby machines should be used the plant have minimum total costs.

E.Calculation of Breakdown Maintenance for Truck

Number of truck = 1,200

Breakdown cost/truck = C_b = 1,000,000 kyats

Preventive maintenance cost/truck = C_p = 200,000 kyats

Individual breakdown maintenance cost/truck = C_{bi} = 450,000 kyats

Table III. Breakdowm Data for Truck

Truck use (miles)	Probability of Breakdown (p_i)
1500	0.2
3000	0.1
4500	0.1
6000	0.15
7500	0.2
9000	0.25

F.Calculate the average life between two consecutive breakdown of truck.

$L_{avg} = \sum_{j=1}^{n} i\, p(i)$

Calculate the average numbers of breakdown per miles

$$B_{avg} = \frac{\text{total number of truck}}{L_{avg}}$$

Calculate the expected total cost

$$TC_b = Cb \times B_{avg}$$

G.Calculate the Expected Total Costs of Preventive Maintenance Policy

The expected no of breakdown of preventive maintenance

(1) every 1500 miles

$B_1 = N \times P_1$

(2) every 3000 miles

$B_2 = N (P_1 + P_2) + B_1P_1$

(3) every 4500 miles

$B_3 = N (P_1 + P_2 + P_3) + B_2 P_1 + B_1P_2$

(4) every 6000 miles

$B_4 = N (P_1 + P_2 + P_3 + P_4) + B_3 P_1 + B_2P_2 + B_1P_3$

(5) every 7500 miles

$B_5 = N (P_1 + P_2 + P_3 + P_4 + P_5) + B_4 P_1 + B_3P_2 + B_2P_3 + B_1P_4$

(6) every 9000 miles

$B_6 = N (P_1 + P_2 + P_3 + P_4 + P_5 + P_6) + B_5 P_1 + B_4 P_2 + B_3 P_3 + B_2 P_4 + B_1 P_5$

H. Calculation of Standby Machine for Truck

Plan of stand by machine for truck calculation for probability of failures

Poisson Distribution

$$P_n = \frac{e^{-\lambda}\lambda^n}{n!}$$

λ= average of machines undergo repairs = 4 machines

e= 2.7183

Stand by cost = 50,000 kyats/day

Loss in work and service = 120,000 kyats / machine/day

Conditions get serious when five or more machines are out of operation at once.

So, addition loss = 450,000 kyats

Minimum total cost = 292,970 kyats

Four standby machines should be used the plant have minimum total costs.

III. RESULTS AND DISCUSSION

The purpose of this thesis was to develop a maintenance plan for three-wheels roller and truck owned by highway department. They are having breakdowns and problems with their heavy machinery that is exposing their workers to risks and costing the department money. These troubles are believed to be related to inadequate field maintenance of their three-wheels roller and truck. The goal of this thesis was to provide a plan to help improve thesis conditions.

Basic risk management principles were also reviewed because the department considered it imperative to integrate them when controlling these losses. From the results, the highway department could benefit from a preventive maintenance plan. Such a plan could help protect workers and company assets.

Management needs to provide an expectation of minimum care standards to be used in the maintenance and repair of highway department's three-wheels roller and truck heavy machinery.

Table IV. Results Data of Total Preventive Maintenance Cost for Three-Wheels Roller

Hours Plan	Total preventive Maintenance cost (TPM) (kyats)	TPM/1000hrs (kyats)
2000 hours plan	301,500,000	301,500,000
3000 hours plan	307,500,000	153,750,000
4000 hours plan	334,515,000	111,505,000
5000 hours plan	370,560,000	92,640,000
6000 hours plan	411,540,000	8,230,800
7000 hours plan	433,440,000	72,240,000
8000 hours plan	452,670,000	64,667,142.8
9000 hours plan	456,810,000	57,101,250
10000 hours pla	464,880,000	51,653,333.33

Minimum preventive maintenance cost/1000 hrs

= 51,653,333.33 kyats

Choose 10000 hours plan for maintenance policy

Total breakdown maintenance cost /1000hrs

=2477876100 kyats

The best policy therefore is to have preventive maintenance for Three-Wheels roller.

Table V. Results Data of Preventive Maintenance Policies for Truck

Preventive maintenance every miles	Total expected Breakdowns in Every miles	Mean no. of Breakdown per 1500 miles	Expected breakdown cost per 1500 miles (kyats)	Expected preventive maintenance cost per 1500 miles (kyats)	Expected cost total 1500 miles maintenance Policy (kyats)
1500	240	240	108,000,000	200000	108,200,000
3000	408	204	91,800,000	100000	91,900,000
4500	585.6	195.2	87,840,000	66666.67	87,906,666.67
6000	841.92	210.48	94,716,000	50000	94,766,000
7500	1203.744	240.7488	108,336,960	40000	108,376,960
9000	1692.7008	282.1168	126,952,560	33333.33	126,985,893.3

The best preventive maintenance policy in every 4500 miles

TC_p = 87,906,666.67 kyats

Since total cost for breakdown maintenance

TC_b = 1,894,737,000 kyats

$TC_p < TC_b$

The best policy therefore is to have preventive maintenance for truck.

Table VI. Results Data of Poisson Distribution for Three-Wheels Rollers and Truck

Poisson Distribution (P_n)	Values	
	Three-wheels Rollers	Truck
P_0	0.0498	0.018
P_1	0.149	0.073
P_2	0.224	0.146
P_3	0.224	0.195
P_4	0.168	0.195
P_5	0.101	0.156
P_6	0.0504	0.104
P_7	0.0216	0.059
P_8	0.008	0.030
P_9	0.003	0.013

Table VII. Results Data of the Optimum Number of Standby Machines for Three-wheels Rollers

No of Standby m/c	0	1	2	3	4	5	6	7	8	9	Lost cost (kyats)	standby cost (kyats)	total cost (kyats)
	0.0498	0.149	0.227	0.224	0.168	0.101	0.0504	0.0216	0.008	0.003			
0	0	100000	200000	300000	400000	500000	800000	900000	1000000	1100000	315660	0	315660
1		0	100000	200000	300000	400000	500000	800000	900000	1000000	210686	20000	230680
2			0	100000	200000	300000	400000	500000	800000	900000	126360	40000	166360
3				0	100000	200000	300000	400000	500000	800000	67160	60000	127160
4					0	100000	200000	300000	400000	500000	67160	80000	147160
5						0	100000	200000	300000	400000	12960	100000	112960
6							0	100000	200000	300000	4660	120000	124660
7								0	100000	200000	1400	140000	141400
8									0	100000	300	160000	160300
9										0	0	180000	180000

Table VIII. Results Data of the Optimum Number of Standby Machines for Truck

No of Stand by m/c	0	1	2	3	4	5	6	7	8	9	Lost cost (kyats)	standby cost (kyats)	total cost (kyats)
	0.018	0.073	0.146	0.195	0.195	0.156	0.104	0.059	0.03	0.013			
0	0	120000	240000	360000	480000	1050000	1170000	1290000	1410000	15300000	631380	0	631380
1		0	120000	240000	360000	480000	1050000	1170000	1290000	1410000	444660	50000	494660
2			0	120000	240000	360000	480000	1050000	1170000	1290000	290100	100000	390100
3				0	120000	240000	360000	480000	1050000	1170000	173310	150000	323310
4					0	120000	240000	360000	480000	1050000	92970	200000	292970
5						0	120000	240000	360000	480000	43680	250000	293680
6							0	120000	240000	360000	18960	300000	318960
7								0	120000	240000	6720	350000	356720
8									0	120000	1560	400000	401560
9										0	0	450000	450000

Figure 7. Three-Wheels Roller (Sakai R2H-2K 3)

Figure 8. Truck

IV. CONCLUSIONS

In this study, breakdown maintenance cost for three-wheels roller was 2,477, 876,100 kyats and preventive maintenance cost was 51,653,333.33 kyats. The best policy therefore is to have preventive maintenance for three-wheels roller. Moreover, five standby machines should be used the plant have minimum total cost, about 112,960 kyats.

The result of breakdown maintenance cost for truck was 1,894,737,000 kyats. The best preventive maintenance policy in every 4500 miles for truck was 87,906,666.67 kyats. The best policy therefore is to have preventive maintenance for truck. Finally, four standby trucks should be used the plan have minimum total cost about 292,970 kyats.

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