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# Total Productive Maintenance And Performance: A Malaysian SME Experience

Halim Mad Lazim*, T. Ramayah** and Norzieiriani Ahmad***

*The importance of maintenance has been emphasized especially in the manufacturing environment. The failure of equipments or machines to produce products on time as required can reflect the inefficiency in operations thus, failure to deliver the products to the customers. The objective of TPM is to create an active participation of all employees in maintenance and production functions, including the operators who operate the machines and equipments. This paper discusses part of a preliminary study finding focusing on two main TPM practices namely autonomous maintenance and planned maintenance in a Malaysian SME. The results suggest important aspects of autonomous maintenance and planned maintenance activities that contributed to the improvement in quality and cost.*

Field of Research: Operations Management, Total productive maintenance (TPM)

## 1. Introduction

TPM is a comprehensive, resource-based maintenance management system that strongly focuses on improving equipment effectiveness, productivity and eliminating production losses. Total participation from all employees including top management and operators are vital in TPM. More importantly, the role of top management stimulates the contribution of operators to achieve zero breakdowns, zero stoppages and safer working environment.

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***Halim Mad Lazim, Faculty of Technology Management, Universiti Utara Malaysia, email: mlhalim@uum.edu.my**
****Assoc. Prof. T. Ramayah, Technology Management Lab, School of Management, Universiti Sains Malaysia, email: ramayah@usm.my**
*****Norzieiriani Ahmad, Faculty of Business Management, Universiti Utara Malaysia, email: norzie@uum.edu.my**

Moreover, TPM consolidates the preventive and predictive maintenance approaches with the emphasis on employee participation. However, in order to enable employee participation, training and education should be provided sufficiently. The elements of training not only very important in any organization, regardless whether they are manufacturing or services oriented. Thus, training plays an important role in minimizing the negative effect of system complexity on manufacturing system performance (Guimaraes et al. 1999). However, in TPM implementation various authors stressed the contribution of training towards performance such as Tsarouhas (2007), Ireland and Dale (2006), Sharma et al (2006) and Ahamd et al (2005).

Historically, there are three eras of maintenance in Japan, where TPM originated (Nakajima, 1988). The first era, is known as preventive maintenance era (1950's) that emphasizes on establishing maintenance functions. The second era (1960's) is the introduction of productive maintenance, where maintenance prevention, reliability, maintainability engineering took place. However, the third era, total productive maintenance in 1970's put emphasis on total employee participation and strong support from top management. The employee involvement is nonetheless very essential particularly the operator who operates the equipment. Any abnormalities detected can be triggered as soon as possible with regards to training and education and, provided sufficiently. Moreover, it is very important to follow-up on any training and education program in order to ensure operators commitment; skills and knowledge are at exceptional level. Furthermore, through total employee involvement, the skepticism of maintenance as a support function, non-productive and not a core function thus adding little value to the business (Bamber et al 1999), can be avoided. Basically, there are lot of advantages can be achieved through TPM implementation. For instance, TPM can lead to the improvements in quality cost delivery and flexibility (Sharma et al., 2006, Seth & Tripathi, 2005, 2006; Cua et al., 2001; McKone et al., 2001).

## 2. Literature Review

The nature of maintenance work has changed in recent decades as a result of a huge increase in the number and variety of physical assets to be maintained, increasing automation and complexity, new maintenance techniques and changing views on maintenance organization and responsibilities The nature of maintenance work has changed in recent decades as a result of a huge increase in the number and variety of physical assets to be maintained, increasing automation and complexity, new maintenance techniques and changing views on maintenance organization and responsibilities (Moubray, 1997). According to Murthy, Atrens, and Ecceleston (2002), up to 1940, maintenance was considered an unavoidable cost and corrective maintenance was the only approach. Therefore, maintenance job was observed as fire fighting activity. According to Al-Najjar and Alsyouf (2003) maintenance function has been more challenging in order to maintain and improve product quality, safety requirements and plant cost effectiveness. The new technologies and automation cannot be denied as they establish very efficient operations in manufacturing companies. However, in order to ensure all operations are smooth, therefore equipment breakdowns and stoppages must be avoided.

The operators who operate the equipment and maintenance specialist should work closely to ensure any abnormalities can be detected as early as possible. Through TPM, the resources available at all levels work closely to achieve desired goals. More importantly, TPM helps equipment attain zero breakdowns, zero stoppage and increase availability and reliability as well (Nakajima, 1988). TPM integrates preventive maintenance, condition-based maintenance and predictive maintenance activities as well. In fact, in TPM, periodic maintenance is towards predictive maintenance, which can detect any equipment deterioration and failure more effectively using new embedded technology and condition-based inspection technology such as vibration analysis, fluorescence spectroscopy, infrared thermography, tribology and oil analysis, and others (Parida & Kumar, 2006). Basically, TPM operates through the 8 important pillars to support its implementation effectively, which:

1. Increase overall equipment effectiveness
2. Training and education
3. Autonomous maintenance
4. Early equipment management
5. Planned maintenance
6. Quality maintenance
7. Office TPM
8. Safety, health and environment

All the 8 pillars put a strong emphasis on continuous process improvement through comprehensive and systematic maintenance management. The issue of ensuring uninterrupted daily operation, zero accidents and breakdowns, administrative, training and education etc are highlighted sufficiently. However, the most important thing to ensure successful TPM implementation relies on strong support and commitment from top management. Additionally, Hansson, Backlund, and Lycke (2003) put forward the importance of top management leadership to focus on strategic planning, training and education, monitoring and evaluation, empowerment, and information and communication in increasing the successful implementation of not only TPM but TQM and RCM (Reliability Centered Maintenance) also. More importantly, Tsang and Chan (2000) revealed the importance of management leadership, employee involvement, education and training, strategic planning and communication for TPM in a high-precision machining company, located in Pearl River Delta, China. Cooke (2000) also identified top management support, alignment of management initiatives and change, employee training, autonomy to employees and communication as important factors for the success of TPM in a European context. Researchers, for instance, Sharma, Kumar, & Kumar (2005) and and

Ljungberg (1998) put definition of TPM in terms of overall equipment effectiveness (OEE) from a generic perspective. OEE also contributes to increased profit and reduced manufacturing cost using OEE calculation methodology (Kwon & Lee, 2004). Significant improvements have been recorded in manufacturing costs and profits of more than USD389 thousands (Kwon & Lee, 2004). Generally, TPM puts emphasis on equipment losses elimination. These losses can be categorized into three main categories; namely downtime, speed losses and defects (Nakajima, 1988). Table 1 illustrates the detailed description of losses.

**Table 1: Description of losses**

| Types of losses | Characteristics |
|---|---|
| Downtime/breakdown [a] | Equipment failure – from **breakdowns.** These failures are due to chronic/sporadic losses<br>**Set-up and adjustment** – from exchange of die in injection molding machines, etc |
| Speed losses [b] | **Idling and minor stoppages** – due to the abnormal operation of sensors, blockage of work on chutes, etc.<br>**Reduced speed** – due to discrepancies between designed and actual speed of equipment |
| Defect:/rework [c] | **Process defects and rework** – due to scraps and quality defects to be repaired<br>**Start-up loss** (reduced yield) – from machine start-up to stable production |
| Notes: [a] Equipment availability; [b] performance efficiency; [c] quality rate | |

Source: Nakajima (1988), p. 14.

On the other hand, Venkatesh (2006) explores the six big losses and re-categorised them into 16 types of losses as highlighted in Table 2.

**Table 2: Types of Losses**

| Losses Category | | |
|---|---|---|
| Equipment efficiency related | Human work related | Effective usage of production sources related |
| • Failures<br>• Set-up/adjustment<br>• Cutting blade loss<br>• Start up losses<br>• Minor stoppages<br>• Speed losses<br>• Defect/rework loss<br>• Scheduled downtime loss | • Management loss<br>• Operating motion loss<br>• Line organization loss<br>• Logistic loss<br>• Measurement and adjustment loss | • Energy loss<br>• Die, jig, and tool breakage loss<br>• Yield loss |

Downtime and breakdown losses (time losses) will be used for calculating the availability of equipment. Meanwhile, speed losses are used to measure the equipment efficiency. Additionally, defect/rework losses are considered as quality losses and increasing number of defects and reworks reflect the quality of products produced. Overall equipment effectiveness (OEE) is a function of availability (A), performance efficiency (P) and quality rate (Q). The OEE calculation can be simplified as, OEE = (A) x (P) x (Q).

$$OEE = A \times P \times Q$$

$$\text{Availability (A)} = \frac{\text{loading time} - \text{downtime}}{\text{Loading time}} \times 100\%$$

$$\text{Performance (P)} = \frac{\text{processed amount} \times \text{ideal cycle time}}{\text{Operating time}} \times 100\%$$

$$\text{Quality (Q)} = \frac{\text{processed amount} - \text{defect amount}}{\text{Processed amount}} \times 100\%$$

OEE will increase as equipment availability, equipment performance and quality rate increase accordingly. High equipment availability means that chronic and sporadic losses are very low. Adjustments of jigs and fixtures, for instance are done using the single minute exchange of die concept or SMED (Shirose, 1995). On the other hand, performance of equipment can be increased when idling and minor stoppages are tackled appropriately. However, reduced speed due to mechanical or quality problem can hinder performance of equipment as well. Long-period stoppages due to holidays, no materials supply, and periodic repairs are examples of start-up losses that can affect quality rate. Moreover, reworks and rejects also contribute to volume losses thus quality rate as well.

## 3. Methodology

A case investigation was conducted in a large company which has been implementing TPM since 2001. The company selected for this study is one of the leading suppliers of various automotive components, such as beltline moulding part, weather strip, pillar drip moulding, and plastic moulding parts. It is located in an industrial zone in Malaysia. Its annual turnover in fiscal year of 2005-2006 was more than 400 million Ringgit Malaysia (RM); (RM3.40 = USD1). The staff size was about 1500 of which includes engineering and technical personnel, management and executive, direct workers and indirect supporting staff. The products are for both local markets and export as well. Proton, Perodua (Malaysia), Honda, Isuzu, and Toyota (Thailand) are some of the examples of major car manufacturers and assemblers using parts and components from this company. Automotive components manufacturing business is known to be very competitive. The company had to meet both internal and external pressures like stringent customer requirements, competitive pricing, lead time, zero defects and new advance manufacturing technology adaptation etc. Moreover, the company had to follow strict government regulations and policies on health, safety and environmental issues.

Furthermore, these relevant issues drove the company to implement a continuous improvement program that can ensure uninterrupted operations due to equipment failure or breakdown. The management of the company viewed that maintenance costs increased about 20-30 percent of the production costs. Moreover, emergency repairs were three times more expensive (Sharma et al., 2006). Therefore, TPM was implemented, with all TPM pillars help to sustain competitive advantage and a part of company's strategic plan, the semi-automated assembly production line was selected for carrying a preliminary study. Generally, the goal of this preliminary study was to increase the knowledge of the industry and to investigate TPM practices, namely autonomous maintenance and planned maintenance on manufacturing performance. Basically, these practices are also known as TPM basic practices and highlighted by various researchers such as Brah and Chong (2004); Cua et al., (2001) and McKone et al., (2001). Another objective of this preliminary study is to supply validity of survey instrument as suggested by Mentzer & Flint (1997) and Ellram (1996). A plant visit for extensive interview with Maintenance Manager was conducted using a semi-structured questionnaire. The questions were aimed at obtaining a better understanding of total productive maintenance practices and implementation in the industry. The result of the preliminary study will be presented in the next section.

# 4. Discussion Of Findings

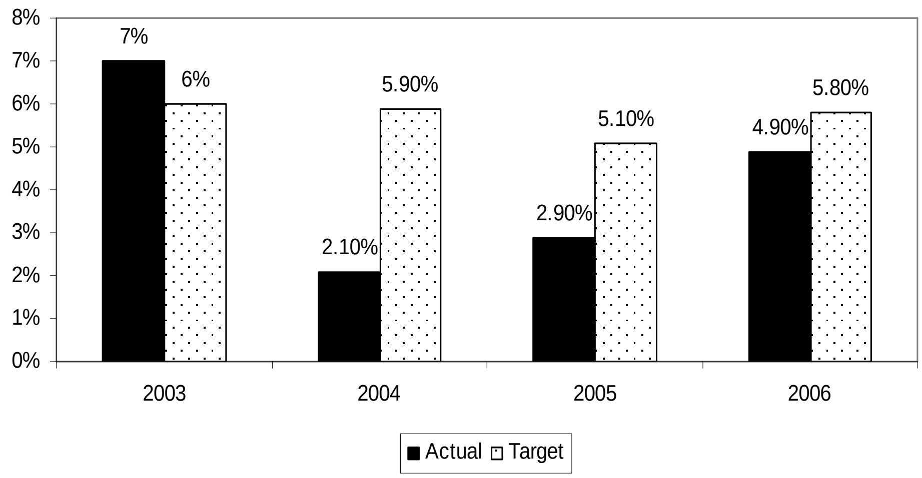
## 4.1 Autonomous Maintenance

The company tried very hard in order to ensure equipment breakdown and stoppages are under reasonable limit. Top management has suggested implementing maintenance program to reduce equipment breakdown and stoppages in the Production line. Most of the time, the maintenance strategy used was corrective maintenance. In fact Swanson (2001) asserts that there are 3 maintenance strategies such as corrective, proactive and aggressive. TPM, for instance is categorised under aggressive maintenance strategy. TPM, which focus heavily on internal resources through total participation from all levels of employees ensure certain objectives and goals set by top management can be attained. However, the effort to put TPM as a continuous improvement program certainly needs proper planning and execution. Therefore, training and education have become one of the important stages in autonomous maintenance.

Training and promotion in TPM were conducted in the introduction of the program back in 2001 and continuously done up until now. The objective of TPM training and education is not only to explain TPM elements and pillars, but also to raise morale and soften resistance to change, in this case, TPM. A campaign to promote enthusiasm for TPM implementation was organized; where banners, signs, flags and notice boards that bear TPM slogans were created in order to have a positive environment effect. TPM awareness was created through banners, posters, streamers and flyers throughout the plant especially in the production lines. Autonomous maintenance requires teamwork from various departments such as production and maintenance to work closely to eliminate any potential breakdowns and stoppages through total commitment.

There are seven stages in autonomous maintenance (Nakajima, 1988), which are conduct initial cleaning and inspection; eliminate sources of contamination and inaccessible areas; develop and test provisional cleaning, inspection, and lubrication standards; conduct general inspection training and develop inspection procedures; conduct general inspections autonomously; workplace organization and housekeeping; and fully implement the autonomous maintenance program. However, for this study, focus is given to the three main activities: training and education, teamwork, housekeeping and employee involvement (McKone et al., 1999). The commitment of top management to smoothen the autonomous maintenance activity cannot be denied. Therefore, the company set up TPM organization structure that was headed by the General Manager. The TPM committees consist of several managers from Production Engineering, Quality, Materials, and Maintenance. Technician and engineers were working together to improve equipment availability and performance. The elementary maintenance jobs such as equipment cleaning, lubricating and bolting were done by operators. However, measures to ensure the basic cleaning and inspection, lubricating, bolting etc were taken seriously through continuous training and education. The result showed that work place management, which emphasized on 5S activities managed to maintain very conducive working environment. For instance, the work place was designed in order to make sure housekeeping activities and materials movements were easy to be conducted. Operators were trained to do light maintenance jobs accordingly. Technicians were monitored periodically and focus more on improvements of equipments performance. Generally, total breakdowns (for press machines, metal cutting machine and injection moulding machine) in this company were 4.22% on average for 2003-2006. However, compared to the target set by the top management, it showed that only for the year 2003 it exceeded the targeted value. Figure 1 depicts the downtime for the stipulated year.

**Figure 1: Downtime for the year 2003-2006**




## 4.2 Planned Maintenance

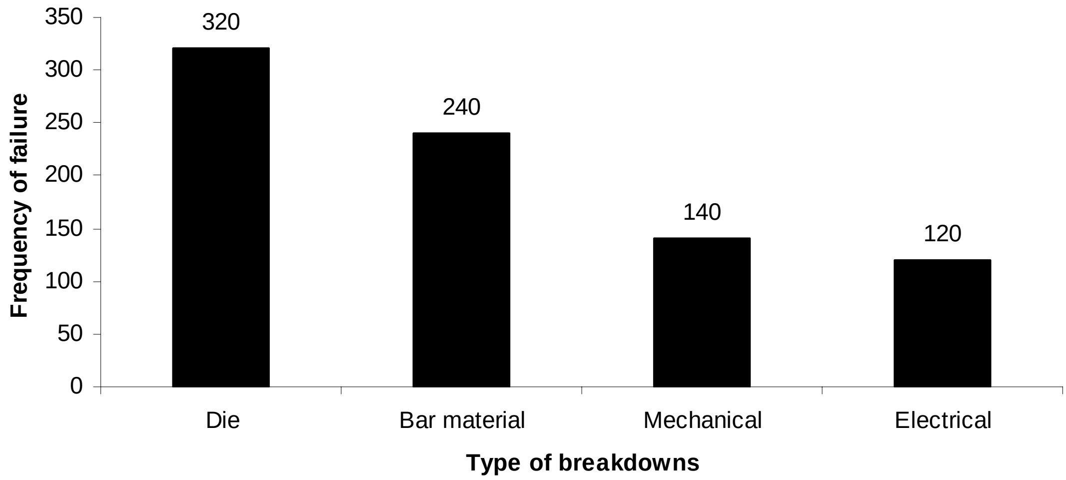
Planned maintenance is one of the TPM pillars. In TPM, planned maintenance aims to evolve from reactive to proactive maintenance approach (Venkatesh, 2006). Moreover, planned maintenance plays an essential role in defining TPM itself, in achieving “total maintenance” concept. There are three main activities in planned maintenance; namely, maintenance prevention, maintainability improvement and preventive maintenance (Nakajima, 1988). Through planned maintenance, total maintenance that refers to “maintenance-free” design incorporated reliability, maintainability and supportability throughout the lifetime of equipment (Sharma et al., 2006). However, in this study, planned maintenance is conceptualised through these activities (McKone et al., 1999): disciplined planning, information tracking, and schedule compliance.

Periodic maintenance was done in order to ensure stoppages and breakdowns were under control. Basically, this company focused more on periodic rather than condition-based in doing maintenance jobs. Maintenance activities were the responsibility of the maintenance department (Production Engineering Department). Daily operations were taken care of by the maintenance supervisors and supported by the production and QMS (Quality Management System) department. Maintenance was organized and carried out with forethought, control and the use of records to a predetermined plan. The purpose of performing preventive maintenance was to minimize and possibly eliminate failures/breakdowns of machines, to investigate and analyze equipment deterioration. However, this company utilised most on periodic maintenance and develop a disciplined planning process for maintenance tasks, such as equipment repair/replacement, and on determining countermeasures for equipment design weaknesses (McKone et al., 1999).

The daily check sheet as well as the monthly check sheet that were done by the operators and monitored by technicians and engineers. All information (i.e. reject rates, rework status, accident status, productivity, quality, overtime costs etc.) was made available to all employees. Specifically, all related information were placed on special area namely TPM Information Corner. The planned maintenance also managed to expose areas that needed improvement urgently. For example, breakdowns of equipment due to die, bar materials, electrical and mechanical failures were easily observed. Then, countermeasures were taken after the technicians analysed the problems and the root causes rectified. On the other hand, breakdowns of die, bar materials, electrical and mechanical failures were the most frequent in this company.

The failure causes however, showed that human related failures also need to be given special attention. Examples were lack of concentration and attention, confusion of cables and wire, loose bolts and nuts, etc. This problem was minimized as training and education in autonomous maintenance was activated on weekly basis rather than monthly basis. Moreover, mechanical failures were associated with failures of components such as gears, bearing, jigs, and tooling. However, electrical failures were usually due to burnt relays and fuses, starters, motors, power supply, and wiring as well. Equipment deterioration and failure due to contaminated hydraulic oils was also discovered especially during shift change. Therefore, technicians inspected all checklists at workstations to ensure the lubricating and topping up hydraulic oils were done sufficiently and correctly. Figure 2 depicts the breakdowns for year 2006.

**Figure 2: Breakdown Frequency in 2006**

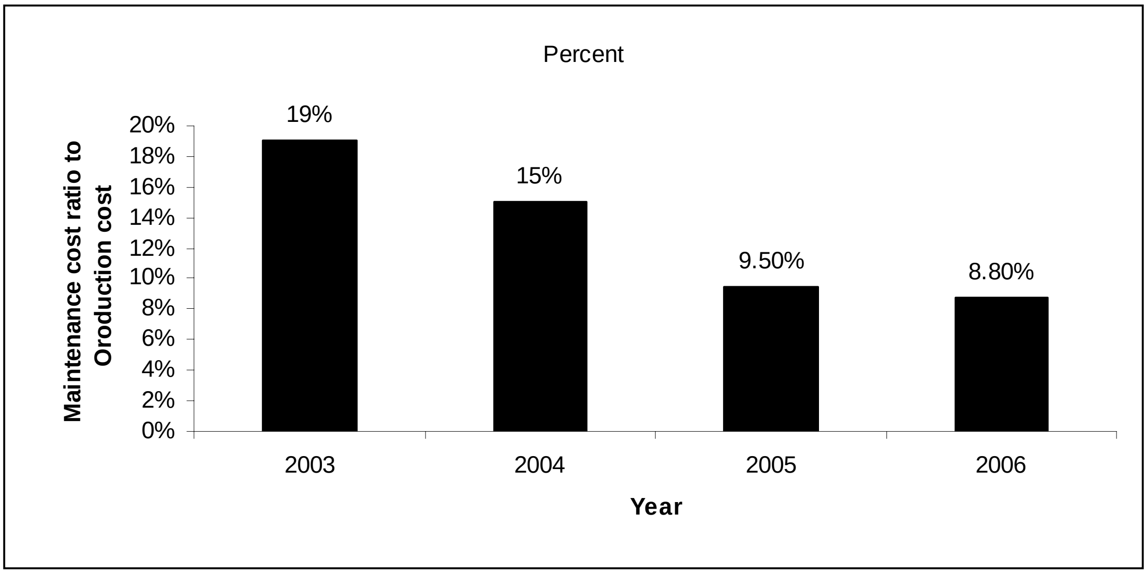



The basic maintenance activities such as highlighted under autonomous maintenance were performed by the operators and planned maintenance activities were carried out by technicians and engineers. The problems were rectified and managed to eliminate rework and reduced reject rates. This also increased the quality of products produced. Table 3 summarises the quality status for the year of 2004-2006. On the other hand, Figure 3 shows Maintenance cost ratio to production cost for the year of 2003-2006.

**Table 3: Reject rates for the year of 2003-2006**

| Types of Reject | Period | | | |
|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2006 |
| Front door sash | 22% | 18% | 16% | 12% |
| Rear door sash | 25% | 17% | 15% | 10% |
| Beltline moulding | 22% | 18% | 15% | 12% |
| Weather-strip moulding | 20% | 18% | 13% | 11% |
| Stamped panel | 21% | 15% | 13% | 11% |

**Figure 3: Maintenance cost ratio to production cost**




## 5. Conclusion And Implications

TPM has been widely known in manufacturing environment. This proactive maintenance strategy contributed to manufacturing performance improvements as highlighted by various researchers (Ahmad et al., 2005; Chand & Srivani, 2000; Jantan et al., 2003; McKone et al., 1999; Suzuki, 1994; Tsang & Chang, 2000; Tsarouhas, 2007). In this study, through TPM process focus, the cost and quality were improved significantly by reducing and minimizing equipment deterioration and failures. Cost of rework and repairs reduced due to very limited products rejected due to equipment failure. Thus, the overall effectiveness of equipment also improved significantly. Additionally, equipment deterioration was eliminated as the equipment operated efficiently. Autonomous maintenance activities were carried out with total employee participation. The investment in training and education managed to boost operators' morale and the commitment towards company's goals. More importantly, manufacturing companies have made investments in TQM and JIT (Just-in-Time) in order to achieve organizational capabilities. However, all those efforts might be unable to achieve desired results due to inefficient equipment with frequent breakdowns and stoppages. Therefore, TPM that incorporates total maintenance concept can be designed to ensure equipment deteriorations are eliminated and the equipment can operate efficiently.

## 6. Suggestions for Future Research

The present study has investigated TPM process focus, namely autonomous maintenance and planned maintenance, and manufacturing performance. Future research could investigate the extent of TPM practices in Malaysian manufacturing companies and to study the relationship of TPM practices and performance. The impact of possible moderating variable such production processes on TPM practices-manufacturing performance relationship could also be tested.

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