Total Productive Maintenance (Tpm) New Trends, Along Energy Fit Plant Maintenance Protocols (2010-2020)

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ABSTRACT

The main goal of this descriptive study is to examine the contemporary High-Performance Manufacturing (HPM) Energy Fit Trends that are triggered by the Total Productive Maintenance (TPM) practices, manifest along the different manufacturing scenarios. The data presented on this study, was gathered from various sources, mainly from the Industrial Maintenance & Plant Operation anual report, as well as from the US Energy Informatión Administratión (EIA).

This analysis explores several theoretical and managerial implications of the TPM practices and their direct articulation with Energy Fit Plant Maintenance Protocols.

KEYWORDS: energy, maintenance, consumption, best practices.

JEL: L60, M11, Q40

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Mantenimiento Productivo Total (Tpm) Nuevas Tendencias, A Lo Largo De Los Protocolos De Mantenimiento De Plantas De Ajuste Energético (2010-2020)

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RESUMEN

El objetivo principal de este estudio descriptivo es examinar las tendencias de ajuste energético en la Manufactura de Alto Rendimiento, que son estimuladas por las prácticas de mantenimiento productivo total, las cuales se requieren a lo largo de los diferentes procesos de fabricación. Los datos presentados en este estudio, se obtuvieron de diversas fuentes, principalmente del informe anual de Mantenimiento Industrial y Operación de las Plantas, así como de la Administración de Información Energética de los Estados Unidos (EIA).

Este análisis explora varias implicaciones teóricas y administrativas de las prácticas del Mantenimiento Preventivo Total y su articulación directa con los protocolos de mantenimiento energetico sostenible.

PALABRAS CLAVE: energía, mantenimiento, consumo, mejores prácticas.

JEL: L60, M11, Q40

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1. Introduction

The constant evolution of quality standards pushes for the proper identification of new performance enhacers defined as "best practices", as well, as for the organizations that are accomplishing these new standards accross the globe.

Along this document, world class organizations/ companies, are going to be defined as "Best Performers" (BP´s), who describe the figure of an industrial plant that has achieved a high reliability and fast throughput of manufactured products and as a consequence, reduce its manufacturing costs, including maintenance costs as well (with low energy consumption patterns) (Dean & Snell, 1991).

Parting from the previously stated, it is of great importance for the Contemporary Manufacturers (CM) to answer the following interrogation: What is the BP´s doing differently than others? The short response to this question, may be supported by the fact that, most of the BP´s across the North American Region, do what all manufacturers around the globe do; although, they just do it for a longer time period (Anita, 2000).

Recent studies helded by EIA, unveil the idea that the nomination of BP´s comes from the fact that these companies know and understand that improved reliability and maintenance performance lies witihin the selection of the most suitable personnel and staff coaching than with technological upgrades (McAdam & Mcgeough, 2000). This does not mean that technology including computer systems and other computer aided design mechanisms are not essential for quality and performance enhacement (Blanchard, 1997). In fact, the implementation of this instruments, contribute to an easier and less time-consuming improvement initiatives (Bamber, 1999). Nonetheless the real challenge on any plant maintenance scenario, comes with the exogenous issues, that often occur over that plant personnel, such as: reactive and undisciplined behaviors that are not attached to the plants maintenance culture or protocols (Cooke, 2000).

Why does this happen? various literature and tests over this topic, suggest that the acquirement of various technological assets, represents the most stress-free and primary processes required, nonetheless, changing the employees behaviors and the regulation of work processes are one of the most complex tasks that a manager must face (Heintzelman, 1976).

It is worth mentioning that the present analysis, focuses on the identificatión and descriptión of the contemperary best practices that are really taken into consideration by the World Class Contemporary Manufacturers, along the Plant Maintenance (PM) framework, by contrasting the different literature and empirical evidence along this subject, that may lead to a general description of the TPM evolution, on this region and the benefits obtained by deploying these measures, that ultimately pursuit cost reduction (Shenoy, 1997).
Stating that one of the central points of this study will be sustained parting from the non-mathematical model, defined by several plant maintenace specialists (Soon, 1999), that have afirm that the key to an optimized Plant Maintenance Best Practices accomplishment, and thereby to an Energy consumption effectiveness, is based upon 3 core variables:

R = Q x A E.

R = Reliability and lower costs
Q = Quality Decisions.
A: Employee Maintenance Protocol Acceptance
E = Execution.

This non-mathematical formula describes the key assets, that every Plant Manager needs to take into consideration, will upgrading any plant maintenance protocol (Soon, 1999), modeled by Christer Idhammar and proven by D. J. Edwards, were essencialy 4 topics are to be considered along each variable of the:

- Reliability and costs minimization through energy fit strategies must taken into consideration.
- The measurement should not be cost/ unit it should be quality unit/cost. Q stands for the right things to do.

- Protocol acceptance must be tested and approved, by the plant supervisors and their personnel.
- After reaching a significant level of acceptance, for your plan, it is entirely up to the Executor (E) to perform the tasks, as scheduled, with the scope as planned. Parting from the above, it is impertaive that, one must create mechanisms to evaluate the correlation between plant maintenance investment strategy versus an overall quality and performance upgrade (PMI, 2013).

2. Literature review

The present analysis intends to collect the theoretical and empirical evidence, related to the contemporary Energy Fit Plant Maintenance theme, along the BP´s global context, with the use several key performances features, pertaining the TPM topic, in order to depict the new trends manifest along this particular manufacturing enviorment and Project management engineering, along the PM enviorment (Robbins, 2003). By taking into account, that Total Plan Maintenance, is the process by which accountable assets in any organization are assist in time, in order for them to be ready when required (Shirose, 1992).

2.1 Plant Maintenance Understanding

The concept of Energy Fit Plant Maintenance Protocols (EFPMP), can be evaluated from a three way perspective: The Japanese Total Plant Maintenance (TPM) versión, as well as the American perspective and a third appreciation that combines both points of view (Japanese and American) modeled since the 1980´s by several scholars, mainly P. Wilmott and S. Nakajima (Nakajima, 1988). When refering to each approach, it is worth stating with the Japanese appreciation, where the Total Productive Maintenance (TPM), refers to the synergistic relationship among all organizational functions, particularly between production and maintenance, in order to continously improve operational efficiency (Hartmann, 1992).

On the other hand,when observing the World Class Manufacturers approach, towards EFPMP, the TPM reflects a profound partnership between the maintenance protocols as well as in the improvement of product quality, with an emphasis on the reduction of manufacturing costs and an overall state of equipment maintenance and a profound pursuit on upgrading the plant performance manufacturing standards (particularly a over the performance enhancement of machines and processes) (Gilbert & Finch, 1985). Nonetheless the third view takes part form the articulation a various Japanese and American Scholars, whose´s agreement, consider 3 common goals that all TPM application must include:

- Zero Defects
- Zero Accidents
- Zero Breakdowns
- Zero Waste

It is worth mentioning that this study will base its literature and empirical review mainly upon the Japanese perspective (Nakajima, 1988), who considers that the TPM core features are based upon five main pillars:

- Focused Improvement.
- Autonomous Maintenance
- Early Equipment Maintenance
- Planned Maintenance.
- Plant Maintenance Coaching/ Training Courses.

Each pillar is going to be linked and correlated with the use of the Christer Idhammar overall model, who generaly explains, that for each item presented on the Japanese TPM basis, describing that for every mayor deviation or variance factor along the plant maintenance activity budget, a common flaw is present, around the implementation of the PM protocols, allocated around the (E) execution variable (Imai, 1986). For instance, when exploring the first pillar, defined as Focus Improvement pillar, it is of great importance to consider the key PM feature are basically conformed upon 2 dimensions: technical breakdown analysis and counter measures against major production losses (Tsang & Chan, 2000). Therefore, focused improvement emphasizes on the setting up of optimal conditions for the functioning and maintenance of equipment capabilities (Hartmann, 1992).

While refering to the Autonomous Maintenance pillar, it is of great importance to consider that when evaluating the execution variable, all operators are responsable to evaluate their own equipment (Imai, 1986), focusing on seven main tasks: A) Initial cleaning and restoration of the equipment B) Identify the source of contamination/áreas dificult to clean C) The establishment of cleaning and lubrication standards D) Undertake overall inspection E) Abide by the Autonomous Schedule and Standards F) Autonomous Supervision to achieve continuos improvement (Hartmann, 1992).

Besides describing the autonomous maintenance pillar, it is of great importance to articulate the execution activities, studied by Idhammar, over the 3 dimensions of the Early Equipment maintenance, who need to be supported by the PM executor, such as the: Development Planning, Lifecycle Costing, and Maintenance Prevention Design (Patterson & Kennedy, 1995).

Finally, while referring to Planned PM, it is of great importance to segregate the different dimensions to which plant maintenance administration maybe divided, who are: predictive planning, preventive planning and specific maintenance breakdown response protocols (Hair, 1998). Where the execution key performance indicator mainly relays on the specific maintenance breakdowns, due to the fact, that these organizations contemplate a more precise categorization of the different phenomena's that may really occur on the plants PM landscape (Bamber, 1999).

2.2 Plant Maintenance Evolution

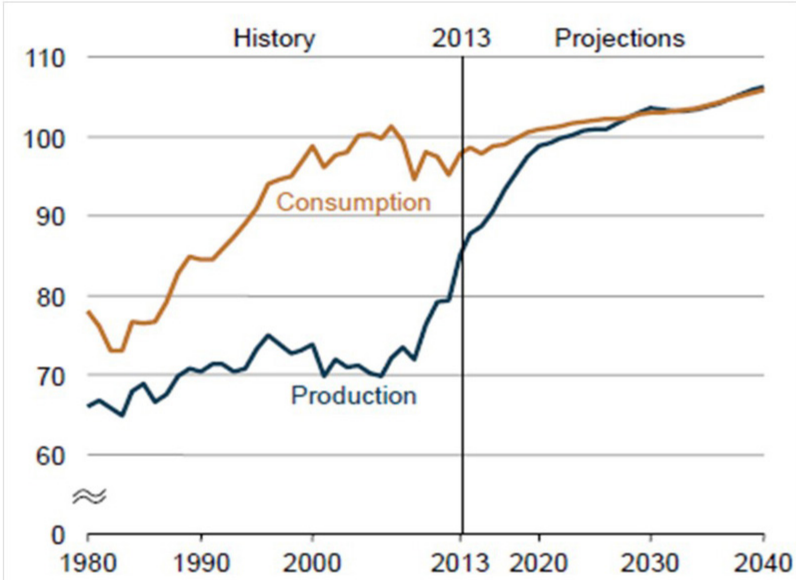
CAs customers requirements evolve, so does the contemporary production technologies in order to match these standards, in a recurrent path that continously liberates new production tools, tecniques, processes and protocols, that have the potential to change the way products are manufactured, in fact, these new tools have the potential to alter the entire production function, including maintenance (Maggard & Rhyne, 1992).

While revising the facts that lead us to the complete understandind of how technological efforts lead to substantial benefits upon cost reductions, it is imperative to describe the differente postulates that are present along this theme. Since Heintzelman and Blanchard (1995), stated that technological efforts are a secondary step, that lead to the TPM Enegergy Fit cost reduction objectives, on the pther hand, Hanna, Keyport and Helfgott, proved that the Advanced Manufacturing Technologies (AMT), who depict the essence of the new production technologies, such as flexible manufacturing systems and computer aided manufacturing, are now able to replace physical and mental human effort (Hanna & Keyport, 1991), as a matter of example, the supervisory computer control systems, who automatically schedule, select part-programs and tool breakage (among other tasks), compensate for tool wear and perform self-diagnostics, used around the globe as a key tool for performance enhancement (Helfgott, 1988). Leading to a new global trend, who is extending around the globe.

Parting from the above, one may infer that the AMT besides, supporting regular primary and secondary activities, it also requires from TPM best practices, who include the core sophisticated task of giving maintenace to it (Gitz, 1992). It is also worth mentioning, that in plants where AMT is in use, the potentially costly consequences of equipment problems also mean that greater attention must be directed toward the prevention of these phenomena and the articulation of JIT in time response protocols to take care of equipment problems (S.Chapman, 1988).

It is worth mentioning, that a global tendency around the AMT has been created, in order to deal with the EFPMP current client demands, by taking as an example the North American model of equilibrium between the industrial energy consumption vs its production, helded on the year 2013 (EIA, 2015), as a result of the efforts for the new production PM best practices to flourish, supported by a strong growth in their domestic oil and dry natural gas production from tight formations and slow growth of total energy consumption (please revise Figure 1).

Figure 1 State of Equilibrium PM reforms in the US, Period 2013-2040



Source: Anual Energy Production Outlook 2015

Figure 1 describes, the general tendency of the energy consumption and production balancing along the US, stimulated by various macro economics pulling factors as well as for the implementation of High Performance Manufacturing Best Practices along their small, médium and large manufacturers, who forecast that the true results of this consolidated efforts, are to be seen on energy imports and exports equilibrium, coming into balance around 2028. Later, from the year 2035 to 2040 (EIA, 2015), energy exports account for about 23% of total annual U.S. energy production and as expected, a general aplication pf the TPM protocols, as well as an adequate economic growth. In the High Economic Growth case, the United States remains a net energy importer through 2040, with net imports equal to about 3% of consumption in 2040. Parting from the above it is imperative to mention that the TPM practices are growing in a similar manner than the AMT´s are evolving.

2.3 Plant Maintenance in Latin America

While describing some global trends along the TPM evolution, it is of great importance to describe several particularities among the TPM evolution and best practices treatment, around the Latin American Manufacturing (LAM) ambience where from the TPM Five Main Pillars, it is documented that only 2 of them are truly accomplished: Autonomous Maintenance and Early Equipment Maintenance, specifically over the Latin American top manufacturers (Mexico, Brasil, Argentina, Chile and Colombia), therefor, it was imperative to detect which TPM practices are truly applied, over the latin american context, please revise table 1, in order to evaluate the practices that are supported by the Latin American manufacturers (Deane, 1990).

Table 2 unveils the fact that around 40% of the TPM Best Practices are deployed along the LAM context, while considering the fact that only 2 of the 5 practices were documented and described. It is also worth mentioning, that from the 2 pillars that were addresed by the LAM, some of the best high-performance practices were documented (FTI, 2015).

Finally, along this theoretical exploration, it is worth mentioning that despite the LAM´s demonstrated few TPM pratices, they presented an upgrade on the energy consumption patterns, due to the Ethanol comercialization efforts and applied AMT´s on the

Table 1 Five Pillars of Supported TPM Quality Assurance

	TPM Five Main Pillars				
	Focused Improvement	**Autonomous Maintenance**	**Early Equipment Maintenance**	**Planned Maintenance**	**Plant Maintenance Coaching**
Japanese TPM 5 Pillars	Not Supported in Latin America	Supported in Latin America	Supported in Latin America	Not Supported in Latin America	Not Supported in Latin America

Note: Self-Interpretation of the Literature compilation TPM Latin America Manufacturers, 2005-2015, by taking into consideration de the R. Dean criteria.

Table 2 TPM Best Practices Undergone on the Latin American Manufacturing Ambience.

	TPM Five Main Pillars	
	Autonomous Maintenance	**Early Equipment Maintenance**
Japanese TPM 5 Pillars	A) The establishment of cleaning and lubrication standards B) Undertake overall inspection	a) Lifecycle costing, b) Maintenance Prevention Design

Source: Self Interpretation of the Literature compilation TPM Latin America Manufacturers, 2005-2015

Brazilian, and Mexican manufacturing plants (FTI, 2015), please revise table 3, in order to confirm these tendencies, that lead to notorious cost reduction energy efforts.

3. Methodology

The methodology implemented along this research is entirely descriptive, due to the study´s main objective, which intends to identify and describe the contemporary trends that have emerge around the TPM energy fit strategies, implemented over World Class Manufacturers (Sampieri, 2013).

In order to execute the previously described research, it was necesary to understand the global high performance TPM best practices, as well as a full trend of the Latin American Manufacturers current status, around the PM energy fit adjustment theme. Besides describing the core TPM energy fit trends, it is worth mentioning that these research, has narrated the evolution of the TPM´S best pratices on the globe.

The theoretical inputs are part of the EIA reports, that were gathered and analysed from the 2010 statistics.

4. Results

Parting from the exploration of the different literature it is of great importance to infer that throught the TPM evolution, along the LAM´s ambience, a strong bond between the TPM and the ATM´s practices was found.

Table 3 Latin America Consumption Report and Forecast 2012-2040

Shipments, prices, and consumption	Reference case							Annual growth 2013-2040 (percent)
	2012	2013	2020	2025	2030	2035	2040	
Refining consumption								
Liquefied petroleum gas heat and power[2]	0.01	0.00	0.00	0.00	0.00	0.00	0.00	--
Distillate fuel oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Residual fuel oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Petroleum coke	0.54	0.53	0.39	0.42	0.41	0.42	0.43	-0.8%
Still gas	1.41	1.47	1.61	1.63	1.59	1.61	1.60	0.3%
Miscellaneous petroleum[3]	0.01	0.01	0.03	0.01	0.02	0.01	0.02	2.1%
Petroleum and other liquids subtotal	1.97	2.03	2.04	2.06	2.02	2.03	2.04	0.0%
Natural gas heat and power	1.23	1.30	1.19	1.17	1.20	1.25	1.31	0.0%
Natural gas feedstocks	0.32	0.31	0.31	0.31	0.32	0.34	0.35	0.5%
Natural-gas-to-liquids heat and power	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Natural gas subtotal	1.55	1.60	1.50	1.48	1.52	1.59	1.66	0.1%
Other industrial coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Coal-to-liquids heat and power	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Coal subtotal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Biofuels heat and coproducts	0.73	0.72	0.80	0.80	0.80	0.81	0.86	0.6%
Purchased electricity	0.20	0.21	0.16	0.15	0.15	0.16	0.16	-0.8%
Delivered energy	**4.45**	**4.56**	**4.50**	**4.48**	**4.49**	**4.59**	**4.73**	**0.1%**
Electricity related losses	0.41	0.42	0.31	0.29	0.29	0.30	0.31	-1.1%
Total	**4.86**	**4.98**	**4.81**	**4.78**	**4.78**	**4.90**	**5.04**	**0.0%**
Total industrial sector consumption								
Liquefied petroleum gas heat and power[2]	0.26	0.29	0.32	0.36	0.38	0.38	0.38	1.0%
Liquefied petroleum gas and other feedstocks[2]	2.16	2.22	2.89	3.21	3.35	3.31	3.30	1.5%
Motor gasoline	0.24	0.25	0.26	0.26	0.25	0.25	0.25	0.0%
Distillate fuel oil	1.28	1.31	1.42	1.38	1.36	1.34	1.35	0.1%
Residual fuel oil	0.07	0.06	0.10	0.14	0.13	0.13	0.13	2.9%
Petrochemical feedstocks	0.74	0.74	0.95	1.10	1.14	1.17	1.20	1.8%
Petroleum coke	0.70	0.65	0.59	0.65	0.63	0.63	0.65	0.0%
Asphalt and road oil	0.83	0.78	1.01	1.09	1.15	1.19	1.25	1.8%
Still gas	1.41	1.47	1.61	1.63	1.59	1.61	1.60	0.3%
Miscellaneous petroleum[3]	0.38	0.63	0.46	0.43	0.46	0.47	0.49	-0.9%
Petroleum and other liquids subtotal	8.08	8.40	9.61	10.24	10.44	10.47	10.59	0.9%
Natural gas heat and power	6.50	6.72	7.05	7.11	7.27	7.38	7.51	0.4%
Natural gas feedstocks	0.89	0.90	1.28	1.36	1.37	1.38	1.39	1.6%
Natural-gas-to-liquids heat and power	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Lease and plant fuel[4]	1.43	1.52	1.87	1.98	2.10	2.18	2.29	1.5%
Natural gas subtotal	8.82	9.14	10.20	10.44	10.75	10.94	11.19	0.8%
Metallurgical coal and coke[5]	0.60	0.60	0.61	0.58	0.53	0.48	0.45	-1.0%
Other industrial coal	0.87	0.88	0.93	0.95	0.96	0.97	0.99	0.4%
Coal-to-liquids heat and power	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Coal subtotal	1.47	1.48	1.54	1.53	1.48	1.44	1.44	-0.1%
Biofuels heat and coproducts	0.73	0.72	0.80	0.80	0.80	0.81	0.86	0.6%
Renewables[6]	1.51	1.48	1.53	1.60	1.59	1.58	1.63	0.4%
Purchased electricity	3.36	3.26	3.74	3.98	4.04	4.05	4.12	0.9%
Delivered energy	**23.97**	**24.48**	**27.42**	**28.58**	**29.10**	**29.29**	**29.82**	**0.7%**
Electricity related losses	6.87	6.72	7.51	7.88	7.88	7.83	7.85	0.6%
Total	**30.84**	**31.20**	**34.93**	**36.46**	**36.98**	**37.12**	**37.68**	**0.7%**

Source: Anual Energy Production Outlook, EIA 2014-2015

Another issue to outstand is the fact that during the compilation of the literature, a profound gap of empirical evidence was identified while exploraing the LAM´s TPM trends, due to the poor application of the TPM practices evolution, accross the Latin American manufacturing landscape (particularly the textile and automative). It is imperative to mention that despite the deep literature survey, helded on this research, few theoretical evidences was found upon the TPM energy fit practices, revealing a posible flaw in its use. Were from the 5 TPM main pillars, only two of them where properly identified and mentioned on the LAM´s, such as:

- Autonomous Maintenance: Around these TPM pillar, only 2 practices suggest the application of the PM Energy Fit practices, who are:
  The establishment of cleaning and lubrication standards.
  Undertake overall inspection.
- Early Equipment Maintenance: Around these TPM pillar, only 2 practices suggest the application of the PM Energy Fit practices, who are:
  Lifecycle costin
  Maintenance Prevention Design

5. Discussion and limitations

After concluding this study, it is imperative to define that there are two main opportunities for future research from this study:

- First, further work needs to be done to identify in a more specific manner the issues where the TPM and the ATM´s systems articulate along the New Production Technologies evolution.
- The monetary quantification of a linkage between EFPMP new process technologies and choice of

regular TPM maintenance practices along the LAM´s.

Nonetheless, along the various limitations that occur, during the empirical and theoretical gathering, one may define that the lack of Latin American High Performance Manufacturers, publishing their experiences on academic instances, were as other manufacturers, like the US small American Manufacturers coalition, depict their statistics and experiences in a very transparent mean.

Other limitation encountered was due to the lack of application of the TPM best practices, along the Latin American Manufacturers, situation that conditioned the access on determining the use of Energy Fit TPM practices.

6. Conclusions

There is enough evidence to infer that the core performance enhancers along the TPM processes, along the Idhammar model over the EFPMP, on the latin american ambience are:

- Life Cycle Costing
- Maintenance Prevention design

It is also worth mentioning, that theoretical evidence, presente by the EIA, suggests that the TPM variables on Christer Idhammar model over the EFPMP, that need to be strengthen are:

- Establish Cleaning and Lubrication Standards.
- Undertake overall inspection.

Finally, it could be alarming, that approximately only 40% of the new TPM best practices trends could be really applied over the Latin American Manufacturing context, since only two of the 5 TPM pillars are truly exposed by these plants due to the lack of best practices acknowledgemet. Therefor the use of the Energy Fit PM practices was poorly sustained, along this manufacturing ambience.

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