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# IMPROVING PROCESS QUALITY BY NEW LEAN SIX SIGMA METHODOLOGY FOR REVAMPING ONLINE PRODUCTION LINES TRAINING*

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## ABSTRACT:

Factories of today are stuck in severe crisis, so continually striving to improve process quality to reduce both time and costs and add more control procedures to processes. Lean Six Sigma (LSS) derives from Lean thinking and mathematical use of sigma in statistics as a standard deviation for measuring variability; using DMAIC and process mapping to reduce process variation. The LSS process pervades all business aspects such as management, design, production and customer satisfaction.

The chronic problems have a solution in the new LSS using timed place Petri net (TPPN), which is a graphical tool used to control and model functional, information, dynamic behavior and decisions aspects of the interrelationship between processes to understand where and how improvements might be made. So, it help in eliminating the causes of problems that absorb resources and create no value to satisfy customer and commensurate with his needs to reduce the discrepancies between actual and planned.

Value stream mapping (VSM) is LSS tool used to map the current state and to identify source of waste to eliminate, and map the future state. To quantify the benefits gained from using the new LSS tool in the value stream mapping, a TPPN model was developed to provide the VSM with online data, to get a dynamic VSM which make a continuous system control.

This work addresses the application of LSS concepts using TPPN to the continuous production processes sector with a focus on the ceramic industry.

**KEY WORDS:** DMAIC, Lean six sigma, Petri net, Value stream mapping.

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# AMELIORER LA QUALITE DE PROCESSUS DE NOUVEAU METHODOLOGIE LEAN SIX SIGMA DE MODERNISATION EN LIGNE DE PRODUCTION DES LIGNES DE FORMATION

## RÉSUMÉ:

Aujourd'hui, les usines sont coincés dans une crise sévère, de sorte efforçons continuellement d'améliorer la qualité des processus pour réduire les délais et les coûts et d'ajouter des procédures de contrôle davantage au processus. Lean Six Sigma (LSS) dérive de la pensée rationnelle et l'utilisation des mathématiques dans les statistiques sigma comme une déviation standard de mesure de la variabilité; utilisant DMAIC et la cartographie des processus pour réduire les variations de processus. Le processus de LSS imprègne tous les aspects des affaires telles que la gestion, la conception, la production et la satisfaction du client.

Les problèmes chroniques ont une solution dans le LSS nouvelle aide chronométré place de réseaux de Petri (TPPN), qui est un outil graphique utilisé pour le contrôle et le modèle fonctionnel, l'information, le comportement dynamique et les aspects des décisions de la relation entre les processus pour comprendre où et comment des améliorations pourraient être faite. Ainsi, il aide à éliminer les causes des problèmes qui absorbent les ressources et ne créent aucune valeur pour satisfaire la clientèle et correspondant à ses besoins afin de réduire les écarts entre les dépenses réelles et prévues.

Cartographie de la chaîne de valeur (VSM) est un outil utilisé pour la carte LSS l'état actuel et d'identifier la source des déchets à éliminer, et la carte du futur Etat. Pour quantifier les avantages découlant de l'aide du nouvel outil dans la LSS cartographie de la chaîne de valeur, un modèle TPPN été développé pour fournir le VSM avec des données en ligne, pour obtenir un VSM dynamique qui font un système de contrôle continu.

Ce travail traite de l'application des concepts à l'aide LSS TPPN à la production en continu les processus du secteur en mettant l'accent sur l'industrie de la céramique.

**MOTS-CLÉS**: DMAIC, Lean six Sigma, réseau de Pétri, cartographie de la chaîne de valeur.

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## 1. INTRODUCTION

Factory performance remains unpredictable in spite of the considerable literature on manufacturing productivity improvement, and the long history of manufacturing as there is no widespread agreement on how best be performed. Productivity measurement and improvement goes hand in hand, because one cannot improve what one cannot measure. To ensure successfully implementation of continual improvement, a dynamic VSM is used, which is a combination between TPPN and LSS. TPPN is used to model and control processes to provide LSS tools with online data. The lean philosophy will present a good recommend to eliminate waste also six-sigma recommended to increase quality by continuously measure for quality [5]. Bicheno-j in 2000 and 2004 [1,2] show that using the cause and effect Lean also advise to apply a new lean toolbox to integrate lean and six-sigma.

In 2007, the case study factory analyze its performance that shows a potential requirements to improve the process quality to reduce both time, costs and add more processes control. So, the reasons that effect on efficiency must be minimized to increase utilization of resources especially operators [4].

This work uses the DMAIC procedures that collect lean items and six-sigma phases with a TPPN that used to control processes, which must be improved to match the new lean six-sigma, DMAIC is a dependent five phases will expose later.

## 2. DEFINE PHASE

The factory produces bathtubs, which there are obvious variations in productivity, reasons that cause these variations must be listed and defined for processes stages.

The factory consists of seven stages (Oven, forming and cooling, spray, drying, trim, drilling, and finishing) as shown in Fig. (1), the processes are arranged with respect to dependency in SIPOC diagram SIPOC diagram illustrates the inputs effect on processes. It also illustrates the outputs presented with respect to inputs and processes executed. The next phases focus on determine the reasons which effect on productivity and have a relation with inputs/Req's The dependent proc-esses is execute as shown in Fig.(2), the variation is appeared heavily in spray stage which consist of six cabinet, the stoppage reasons is focused on cabinet number 6.

The problem is defined and data collected to feed MiniTab, all of the next figures are outputs depending on these data.

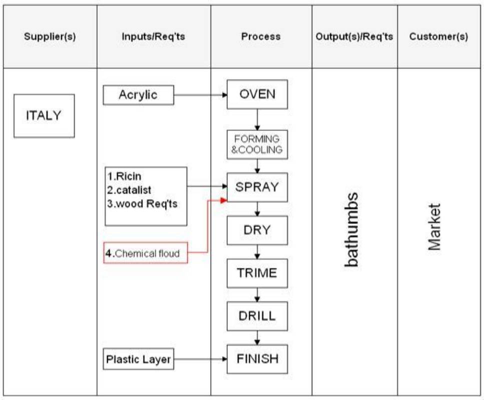


**Fig. (1): SIPOC distributer for input output factors**

### 2.1 Project Charter design

The main step in define phase is shown in the project charter design which shown in Table (1) that illustrate the project charter design, which is a suitable sheet used to expose the objectives of the problem, they started due dates and also the published targets which must be achieved by the next phases of DMAIC.

**Table (1): The project charter design sheet**

| **Project Title** | **Increase productivity in the Factory (Cabin harness)** | | |
|---|---|---|---|
| **Project Leader** | **Eng: Name** | **Site** | **Factory Name** |
| **Objective** | Our aim is to increase productivity in the Factory between 8% : 10%, leading to an equivalent savings in standard hours which will impact the factory indices (E1, E2 & payroll efficiency), with monetary saving value of L.E 77,433.33 | | |
| **tart Date: 13/2/07** | **Completion Date:** | **Team Members (State Core vs. Support)** | **Function** |
| Define | 24/ 12 /2007 | | |
| Measure | 21/ 01 /2008 | | |
| Analyze | 13/ 03 /2008 | | |
| Improve | 06/ 05 /2008 | | |
| Control | 18/ 06 /2008 | | |
| Problem Scope on Describe what is wrong, The scope of the project will focus on Spray area which including direct labor in (cabin harness area number 6), this area consumes about 50% of the standard hours with a low mean efficiency (payroll, E2 & E1) and the highest variability. | | | |
| **Customer Impact** (State the metric as measurable and financial as it relates to business impact), Internally the production will benefit from the improved efficiency figures by the corresponding increase in productivity. | | | |
| **Business Impact** (State the metric as measurable and financial as it relates to customer impact), The expected calculated savings based on the customer plan figures and standard cost rate during 2007 in the Cabin area is L.E. 77,433.33 | | | |
| **Project Metrics** | **Current State(Baseline)** | | **Objective and Stretch Target** |
| Primary1:Efficiency E2 | cabin 6 | E2 | E2 |
| | | 95% | 103% |
| Primary2:Payroll Efficiency | cabin 6 | Payroll eff. | Payroll eff. |
| | | 80% | 92% |
| Secondary (Counter): Quality figures PPM | | | |

The project charter sheet stated as the project metrics, which determine the current state efficiency by 95% and the objective value is 103%. Also determine the current state payroll efficiency by 80% that called for mean value as shown in Fig. (3), and the objective value is 92%, the objective values whether for efficiency or payroll efficiency may be achieved if apply the proposed steps.

The Factory payroll efficiency and its effect on productivity in ceramic industry 2006 is shown in

Fig.(3), that illustrates the output of Minitab sheet for 11 operation executed in Spray area, the standard deviation is 10%, this value can reduced by using the new LSS method which combined with TPPN to improve and control the production line

## 2.2 Cabin Detailed Process Mapping

The process map is a sequential pictorial for the processes execute in the factory, Fig. (2), illustrate the dependency of processes shown in SIPOC, the process map designed by IGrafix software. This figure illustrates the precedence processes required to produce bathtubs.

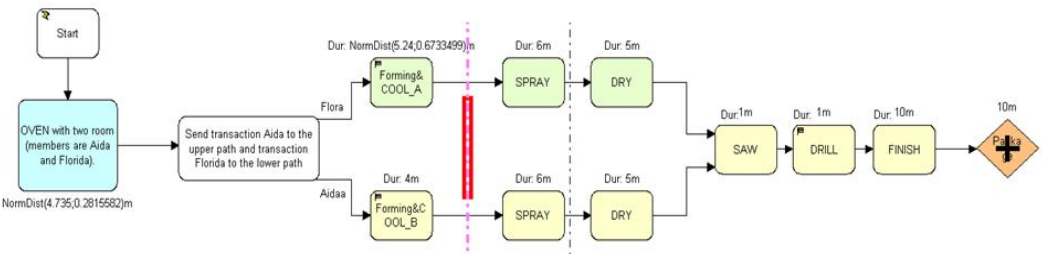


**Fig. (2): The process map for ceramic factory.**

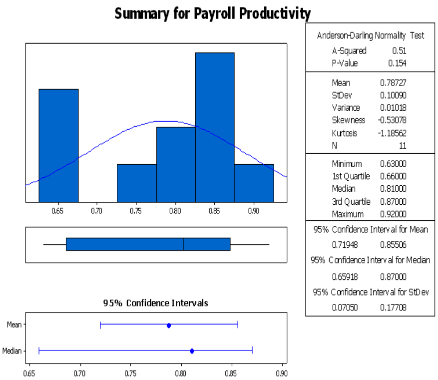


**Fig.( 3): the effective payroll productivity**

## 3. MEASURE PHASE

The measure phase applies on the collected data depending on the SIPOC diagram shown in Fig. (1), and also process mapped shown in Fig. (2), these data is feeder to MiniTab sheet to extract some output results which analyzed to support the decision making.

Data Monitored and collected to improve the process, control the material, transaction and information are as follows:

- The current stoppage sheet "collected in time line 22 weak" is highly effective with coded stoppage reasons.
- The stoppage sheet is updated based on shift.
- The Daily Monitoring report as shown in "(Appendix: A)" is the final summary for stoppage reasons.
- Random Activity Sampling (RAS) is recommended to monitor The Pareto chart shown in Fig. (4) that discuses all causes affect on the production line and leads to the impending doom. The first four causes are neatly monitored to reduce their affects on the efficiency of the production line.

## 4. ANALYSIS PHASE

This phase is important to classify the collected data into category, and determine the main reasons that must be studied to apply the proposed steps. So, this phase focus on the main stoppage reasons shown in Fig. (4), which lead to variation and decrease productivity, these reasons must be eliminated

The stoppage time will decrease the productivity and increase the time and costs, consequently the stoppage time must be reduced, therefore.

The stoppage causes, that shown in the Pareto chart Fig.(5), are the material shortage, sub assembly and MCS leads to lost 18000 sec/week, LSS with TPPN add more control on transactions executed in the shop floor to reduce the stoppage times.

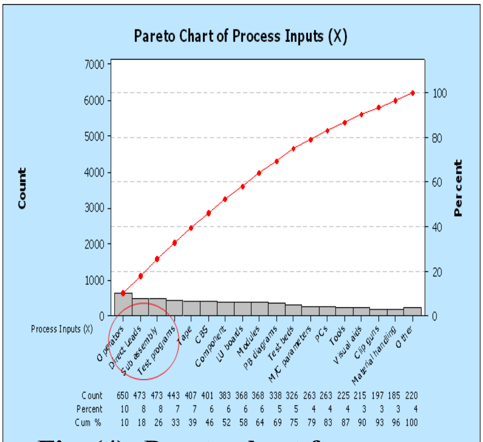


**Fig. (4): Pareto chart for process inputs**

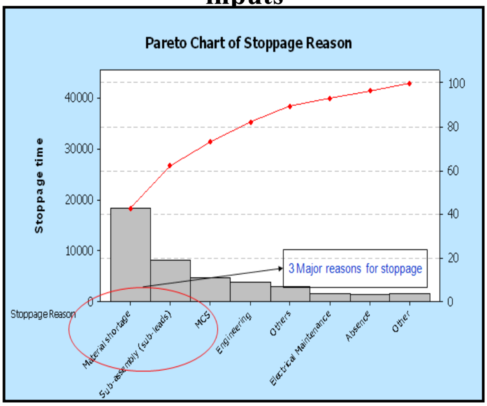


**Fig. (5): Pareto chart for the important 3 major of stoppage**

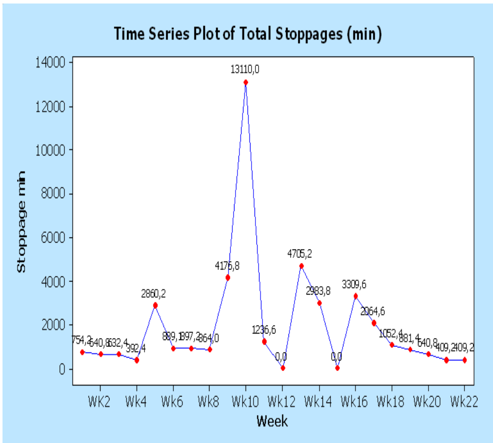


**Fig. (6): Time series plot of total stoppages (min)**

The new LSS is applied until June 2008, during six months the maximum stoppage time illustrated in Fig. (6) is 13110 min in WK10, and this stoppage occurred due to shortage in the material receiving from the suppliers by the deficiencies in the information needed to use the right equipments.

The material shortage is an important reason lead to increase the stoppage line; Fig. (7) shows that foam material lead to stop the line 1 week. So, any material must take importance degree in the production planning.

The second reason is the sub assembly, Fig. (8) shows that the sub assembly reason lead to stoppage time by 1632 min in WK16.

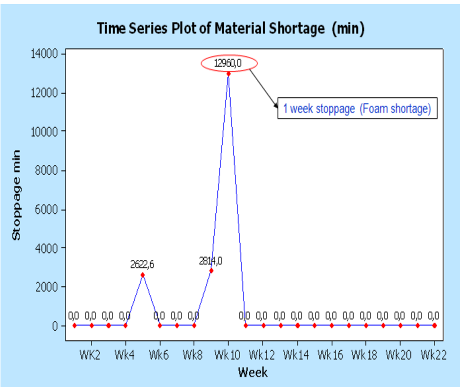


**Fig. (7): Stoppages analysis (shortage material)**

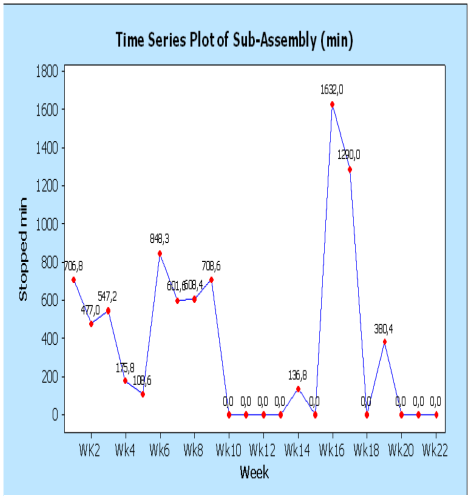


**Fig. (8): Stoppages analysis (subs-assembly)**

The leak in the shortage in material and sub-assembly lead to bad effect on the production, shortage material is steady after week 10, but the sub assembly is still varied, this variation must be reduced, so use random activity sample (RAS) to focus on the reason that occur the maximum variation.

The previous figures indicates that shortage possesses is the most severe effect on production, Sub-assembly stoppages occurs frequently with progressive effect on production rate, the MCS implementation is placed third in severity, to measure this type use a random activity sampling RAS tool.

## 5. IMPROVEMENT PHASE

The random activity sampling is a tool used to focus on the main reason that causes the maximum variation, which is the main reason of stoppage and productivity reduction.

To assess other severe stoppages and delayers during production, which covered in the stoppage sheet, Random Activity Sampling was applied on cabin 6.

Fig. (9) Illustrates the result obtained from applying RAS on cabin 6, which shows that utilization was maximized to 90%. So, it must re-balance the process to increase the efficiency.

## 5.1 Re-balancing

The rebalancing means eliminating waste reasons, Fig. (10-A) illustrate a bottle neck according to the testing process of 6.43 min for each a new target of 70 bathtub/shift, Fig.(10-B) showing an increasing in station 6 by 15%, also Fig.(10-C) showing an improvement in tact time of station 6.

The other sections of the Fig. (10) indicate that to complete the target, which is 70 bathtubs/shift; apply LSS procedures combined with TPPN.

## 6. CONTROL PHASE

Timed place Petri net used to model a continuous production/process sector.

Petri Net is a graphical tool used to control and model functional, information, dynamic behavior and decisions aspects of the interrelationship between processes to understand where and how improvements might be made. So, on line time place Petri help in eliminating the causes of problems that absorb resources and create no value to satisfy customer and commensurate with his needs to reduce the discrepancies between actual and planned by provide LSS tools with online data.

Fig. (11) illustrate the VSM model which shows that activity five is the most over loaded activity because it receives 8 pieces of products out from activity four every 5 min, The problem is improved by simulate the processing time of activity five to optimize the processing time as a normal distribution (NormDist (5.24;0.6733499) *min*) to reduce time variability, also eliminate all aspects of stoppage reasons.

Fig. (12) illustrates the impact on efficiency via TPPN combined with the LSS tools, and shows the effect before and after implementation of the rebalance.

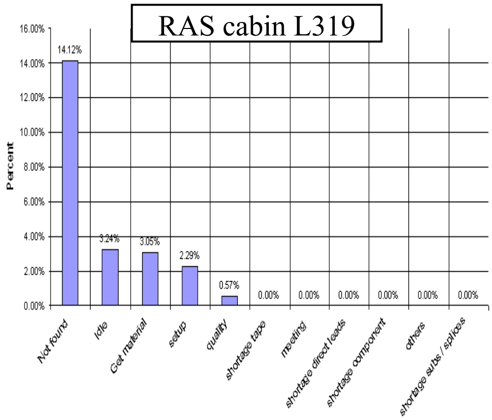


**Fig. (9): Random activity sampling for cabin number 6**

Fig. (13) Illustrates the impact of applying time place Petri net on cabin 6 in the spray area, showing that the production rate is increased by 9% after rebalancing. Its effect on E2 was obvious when compared with the same period in 2007. But when apply rebalancing on MCS E2 increased to 108% against 95% before application. In turn the project calculated saving from August to December 2007 L.E. 46,273.

Table (2), illustrate the results of cabin No. 6, which are the number of cycles per 100 min is 24, and complete 88 different bathtubs. The spray station productivity/day was increased from 374 to 528 p/shift. So efficiency was improved and the standard hour per shift was saved 3hrs.

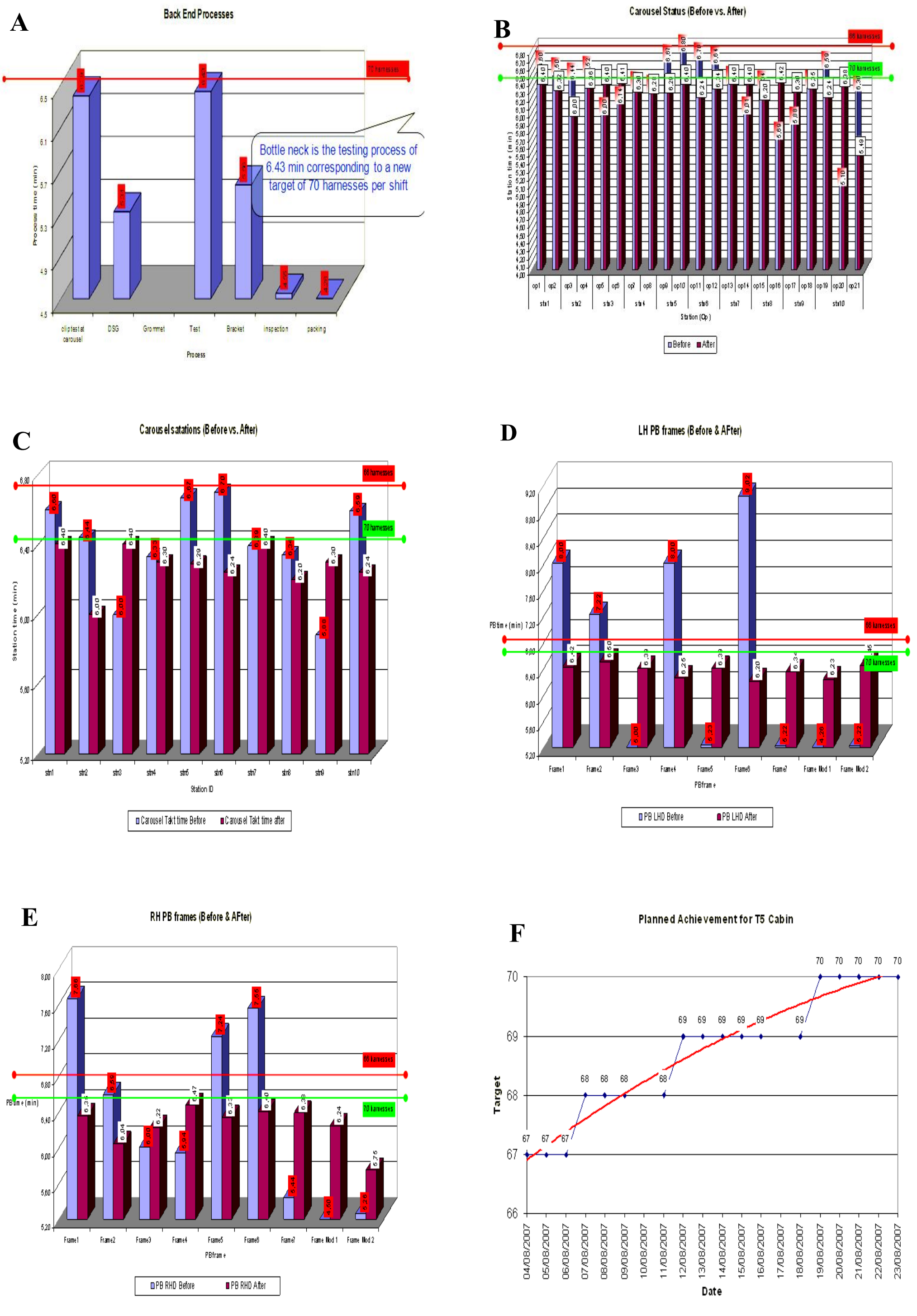


**Fig. (10) A, B, C, D, E, F: Re-balancing of cabin 6.**

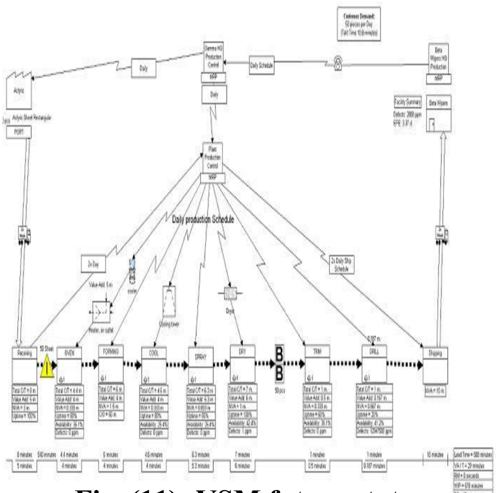

**Fig. (11): VSM future state.**

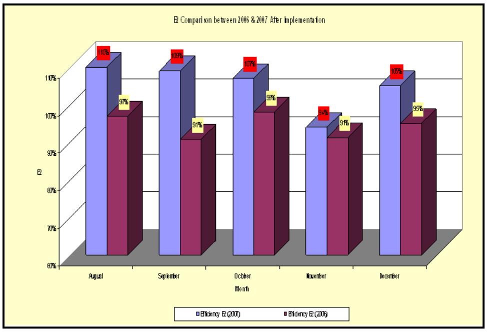

**Fig. (12): Impact on efficiency via LSS thinking**

**Table (2): Current state and future state results of cabin 6**

| Transition | Descriptions for transitions |
|---|---|
| 1 | Oven start |
| 2 | Oven end |
| 3 | Forming start |
| 4 | Forming end |
| 5 | Spray start |
| 6 | Spray end |
| 7 | Drying start |
| 8 | Drying end |
| 9 | Trimming start |
| 10 | Trimming end |
| 11 | Drilling start |
| 12 | Drilling end |
| 13 | Finishing start |
| 14 | Finishing end |

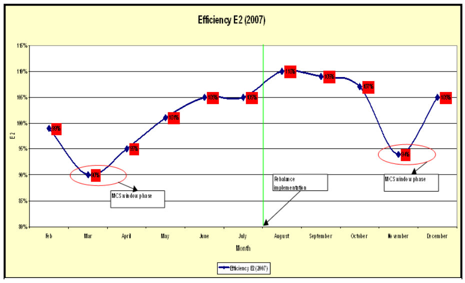


**Fig. (13): Impact of applying time place petri net.**

The Petri net graph shown in Fig. (14), this figure consists of places and transitions, the places represent conditions, resources, and buffers weather transitions represent start and end action for every activity. Table (3) presents descriptions for places showing in Fig.(14). Table (4) presents descriptions for transitions showing in Fig. (14).

**Table (3): Descriptions of places shown in Fig. (14)**

| Place | Descriptions for places | VA time |
|---|---|---|
| 1 | Raw material | 0.0 clock |
| 2 | Oven busy | |
| 3 | Oven available | 5.0 *min* |
| 4 | | |
| 5 | Forming busy | 0.0 clock |
| 6 | Forming available | 0.0 clock |
| 7 | | |
| 8 | Spray busy | 0.0 clock |
| 9 | Spray available | 0.0 clock |
| 10 | | |
| 11 | Drying busy | 0.0 clock |
| 12 | Drying available | 0.0 clock |
| 13 | | |
| 14 | Trimming busy | 0.0 clock |
| 15 | Trimming available | 0.0 clock |
| 16 | | |
| 17 | Drilling busy | 0.0 clock |
| 18 | Drilling available | 0.0 clock |
| 19 | | |
| 20 | Finishing busy | 0.0 clock |
| 21 | Finishing available | 0.0 clock |

**Table (4): Descriptions of transitions shown in Fig. (14)**

| IDIOMS / year | Current State | Future State |
|---|---|---|
| MLT"*min*" | 673 | 588 |
| No. of queues at cell | 4 | 1-2 |
| max_x direction "m" | 140 | 110 |
| Traveling cost/y L.E | £199584 | £156816 |
| Productivity/day | 374 | 528 |
| Cost /product | $2.02 | $1.25 |

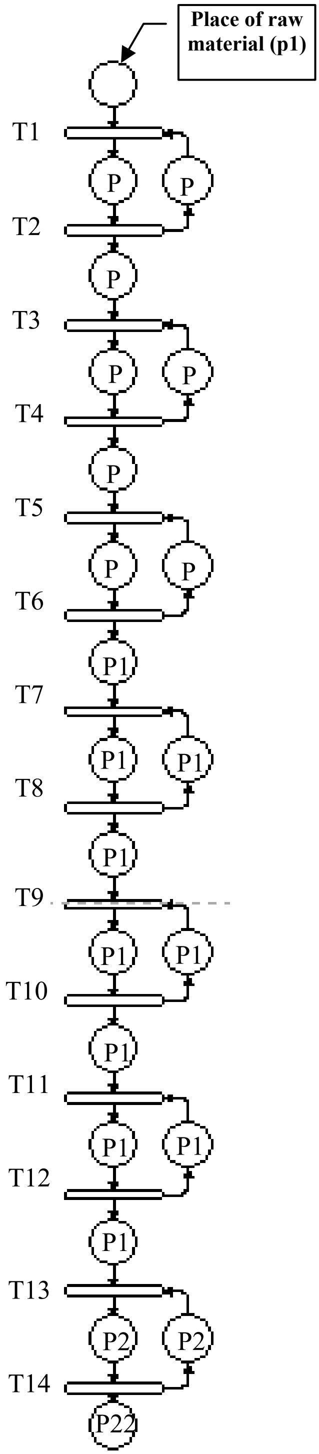


**Fig. (14): Time place petri net used to control productivity**

## 7. CONCLUSION

To the old age, "you cannot improve that which you cannot measure," we add, "you cannot effectively measure that which you cannot on line digitize." This work addresses the application of LSS concepts using online timed place Petri net to the continuous production/ process sector with a focus on the ceramics industry.

Applying LSS improves shop floor more than 60%, and Increases the production rate by 9% with rebalancing, which has an obvious effect on E2 when compared with the same period in 2007. Value stream mapping is used to first map the current state to identify sources of wastes trying to eliminate these wastes which achieved by 60%. The future state map was constructed for the developed system that improved by 9% after applying LSS tool.

But when apply rebalancing on MCS, E2 increased to 108% against 95% before. Intern the calculated project saving from August to December 2007 L.E.46, 273.

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5- Sigma Flow is building an integrated Six Sigma "practitioner' stool set" (http://www.sigmaflow.com) that can be used standalone or integrated with workflow/BPM solutions. For example, they recently announced a partnership with Meta storm (http://www.metastorm.com/news/100903.asp)

6- Sophisticated simulation both of process, and in process, will be an inherent component of Digital Six Sigma, for example see: (http://www.lanner.com/)

7- The Six Sigma Academy (http://www.6-sigma.com) and the International Society of Six Sigma Professionals (http://www.isssp.com/).

8- The New Six Sigma, Motorola University, Matt Barney and Tom McCarty, available from Amazon.com.