DETERMINING THE SAFETY COEFFICIENT IN ORDER TO OPTIMIZE THE SPARE PARTS STOCKS

Ramona Iuliana Popa (Scurtu), Octavian Lupescu, Ionut Ciprian Popa

"Gheorghe Asachi" Technical University of Iasi-Romania, Department of Machine Manufacturing Technology

Corresponding author: Popa Ramona, scurtu_ramona_iuliana@yahoo.com

Abstract: The paper presents the important techniques used for implementation of LEAN strategies in technological equipments maintenance activities. The synthetic indicators for evaluation of acquire performance through LEAN principles and instrumentations applied is Overall Equipment Effectiveness (OEE). OEE is a global parameter that indicates the best value for safety factor because it includes both informations about equipment effectiveness (real cilcul reported to the ideal cycle) and also the quality of obtained parts. Here is presented the theoretical methodology of calculation and its development even a concrete case study, analyzed comparatively with world-class standards. It is also showed the possible direction of continuation of research concerning the analysis of activities, using this value map.

Key words: maintenance, piese de schimb, Lean, Overall Equipment Effectiveness, safety factor.

1. INTRODUCTION

The present globalization of markets, process fully felt also by Romania once she was admitted in UE, means among other things, even a increase of the competition. Since does not exist a previous privilege to stay into the business, each firm must be aware that the survive solution is the continuous effort to grow the competitiveties in a specific area of activities. In this direction, the implementation of LEAN strategy in personal manufacturing and maintenance activities constitute in present the most important system of management in an organization activity.

A definition of LEAN concept (Mobley, 2002), developed by the National Institute of Standards and Technology Manufacturing Extension Partnership`s Lean Network, appreciate that this concept constitute: "*a systematic approach to identifying and eliminating waste through continuous improvement, following the product at the pull of the customer in pursuit of perfection*".

His first definition has at the basis LEAN principles appeared in Japan (Toyota specifically), elements of them were used by Henry Ford in 1920. The aim to define LEAN concept was to describe the working philosophy and practices of the Japanese vehicle manufacturers and in particular the Toyota Production System (TPS) (Paulsen et.al., 1997). In fact, LEAN philosophy represents the definition of "values" for customer; so, all value adding activities can be identify and are named "waste".

LEAN philosophy also recognizes (Taghizadegan, 2006) the seven most important types of wastes, united under the function "*manufacturing waste* - P_f":

$$P_f = f \quad (1)$$

(overproduction, wait time, transportation, processing and complexity, stocks – excess inventory, wasted motions/unutilized talent, errors and defects),

where:

1.*overproduction* – parts, products, etc. are being produced without any new order or demand from the customer ; excess products may be sold with reduced prices at the end of the industry fiscal year to match the budget or lower the inventory for the new year`s production ; this is the most severe waste because persuade directly the other types of wastes ;

2.*delay and wait time* – its caused by the work interruption due to machine or equipment failure or pieces delay that are necessary for manufacturing and/or maintenance;

3.*transportation* – delivery pieces and products useless, as for example from de processing line to warehouse, and from here at the next step of processing, when the last one can be placed in the immediately vicinity of the first step of processing;

4.*processing and complexity* – the realization of any operation needless or incorrectly, due to the spare quality of the equipment;

5.*stocks and excess inventory* – stocking in excess the products and pieces, with no orders, work excess; this will impede and tie up the cash flow;

6.*wasted motions/unutilized talent* – the operators makes motions that are needless as pieces, equipments and documents looking;

7.*errors and defects* – will add additional rework: inspections, design, manufacture and maintenance changes, increases the machine downtime for analyze and resolve the problems.

Consequently, the objective of implementation of LEAN strategy could be synthesized like following:

- reduction of time;
- reduction of space;
- improvement in customer satisfaction, quality, profitability and sales;
- less machines, energy and manpower being utilized in the process.

To establish and verify the desire level of performance it is necessary to identify the types of activities which are display, this could be grouped in:

1. *value adding activities* – represents the activities that, from customer point of view, these make more valuable the products or services;
2. *non-value adding activities* – represents the activities that do not make a product or service more valuable, them can be:
   - non-value adding activities but, are indispensable (about 60% (Musat, 2007));
   - non-value adding activities, and are needless (about 35% (Musat, 2007)).

Per ensemble, this activities must ensure the wastes reduction and elimination, LEAN practices using in this purpose many techniques, named Lean Building Blocks. After (Kilpatrick, 2003), the most used techniques in manufacturing, but also in maintenance are:

- **Pull System** – the technique for producing, for carry on maintenance activities, at demand; it is services (maintenance) organizations technique; manufacturers, on the other hand, have historically operated by a Push System, building products to stock (per sales forecast) without firm customer orders;
- **Kanban -** A method for maintaining an orderly flow of material: material order points, how much material is needed, from where the material is ordered, and to where it should be delivered;
- **Work Cells -** The technique of arranging operations (including maintenance)and/or people in a cell rather than in a traditional straight assembly line; among other things, the cellular concept allows for better utilization of people and improves communication;
- **Total Productive Maintenance -** TPM capitalizes on proactive and progressive maintenance methodologies and calls upon the knowledge and cooperation of operators, equipment vendors, engineering, and support personnel to optimize machine performance; results of this optimized performance include; elimination of breakdowns, reduction of unscheduled and scheduled downtime, improved utilization, higher throughput, and better product quality; bottom-line results include; lower operating costs, longer equipment life, and lower overall maintenance costs;
- **Total Quality Management** – management system of quality that is applicable to every operation in the company and recognizes the strength of employee involvement;
- **Point – Of – Use – Storage** – technique to use pieces stocking;
- **Quick Changeover -** the technique of reducing the amount of time to change a process from running one specific type of product to another; the purpose for reducing changeover time is not for increasing production capacity, but to allow for more frequent changeovers in order to increase production flexibility. Quicker changeovers allow for smaller batch sizes;
- **Batch Sizes Reduction -** manufacturing companies have operated with large batch sizes in order to maximize machine utilization, assuming that changeover times were “fixed” and could not be reduced; because Lean calls for the production of parts to customer demand, the ideal batch size is ONE; however, a batch size of one is not always practical, so the goal is to practice continuous improvement to reduce the batch size as low as possible, so, reducing inventory time (WIP), cycle measure depending of this, so company activities is more profitably, require enables price reductions, increases sales and market share;
- **5 S or Workplace Organization -** This tool is a systematic method for organizing and standardizing the workplace; it’s one of the simplest Lean tools to implement, provides immediate return on investment, and is applicable to every function with an organization; because of these attributes, it’s usually the first recommendation for a company implementing Lean;
- **Visual Conrols -** These are simple signals that provide the existing work situation: production schedule, backlog, workflow, inventory levels, resource utilization, and quality, these controls should be efficient, selfregulating, and worker managed;
- **Concurrent Engineering -** This is a technique of using cross-functional teams to develop and bring new products to market, reduced time-to-market until de products are sold; this time is used as a tools for capturing and maintaining market share.

The Kanban System was developed (more than 20 years ago), by Mr. Taiichi Ohno, a vice president of Toyota, to achieve objectives that include (Smith and Mobley, 2003):

- reducing costs by eliminating waste/scrap
- try to create work sites that can respond to changes quickly
- facilitate the methods of achieving and assuring quality control
- design work sites according to human dignity, mutual trust and support, and allowing workers to reach their maximum potential.

Kanban is a term derived from two Japanese words; *kan* meaning "sign" or "card" and *ban* meaning "signal". This system is used to mark a cycle within the manufacturing process. At one end of this cycle are raw materials, at the other, a completed product.

a Kanban system optimizes the availability of materials, providing just what is needed at any one time. By regulating the flow through the manufacturing environment, inventories are synchronized with need. This contains wasted time and space, keeping costs to a minimum.

Benefits of Kanban:

- The process is simple, understandable and easy to implement.
- Detailed information is readily available.
- Information transfer costs are minimized.
- The process is responsive to environmental and economic changes.
- Amount of processes running over-capacity is limited.
- Overproduction is avoided.
- Waste is reduced.
- Control over inventory, costs and productivity is maintained
- Responsibility is delegated throughout the process.

The most common types of Kanbans that are used today are:

1. Withdrawal (Conveyance) Kan-ban - The main function of a withdrawal Kan-ban is to pass the authorization for the movement of parts from one stage to another.
2. Production Kan-ban - The primary function of the production Kan-ban is to release an order to the preceding stage to build the lot size indicated on the card.
3. Express kan-ban – used when shortages of parts occur
4. Emergency kan-ban – used to replace defective parts and other uncertainties such as machine failures or changes in production volumes
5. Through kan-ban – used when adjacent work centers are located close to each other. It combines production and withdrawal kan-bans for both stages onto one, through, kan-ban

2. METHODOLOGY

The concept of kanban can be used to calculate the minimum stock. Because there are several methods to calculate the kanban, one will be used the most known calculation formulas of it. These formulas are:

$$N = \frac{\left(DD * LT + SS * SQRT\left(\frac{LT}{TB} \right) \right)}{KB + \frac{\left(DD * EPEI \right)}{KB}} \quad (2)$$

where:

DD = Daily demand (units)
LT = Replenishment leadtime (days)
SS = Statistically calculated safety stock (units)
SQRT = Square root
TB = Time bucket of the safety stock data points (days)
KB = Quantity per kanban (units)
EPEI = Supplier's replenishment interval (days)

$$KB = \frac{\left(DD * \left(LT + SS \right) \right)}{KBS + 1} \quad (3)$$

where:

KB = Number of Kanbans
DD = Daily Demand
LT = Lead Time
SS = Safety Stock
KBS = Kanban Size

$$Kanban = \frac{\left(\left(AD * RT \right) + \left(SF * SD \right) \right)}{SCQ} \quad (4)$$

where:

AD = average period demand
RT = replenishment time (in the same time bucket as AD)
SF = the Z factor, typically 1.645 for 95%
SD = demand standard deviation
SCQ = the standard container quantity

$$N = \frac{\left(dL + S \right)}{C} \quad (5)$$

where:

N = number of kanban
d = average demand per hour
L = lead time in hrs
S = safety
C = container quantity

$$K = \left(\frac{\left(RT * AC \right)}{Cont} \right) * \left(SF + C \right) \quad (6)$$

where:

K = number of kanban;
Cont = contents per kanban;
RT = replenishment lead time per kanban;
AC = average consumption per time period;
SF = safety factor;
C = constant, default = 1.

To determine the minimum stock, one developed an algorithm that will be used in order to calculate the Kanban.

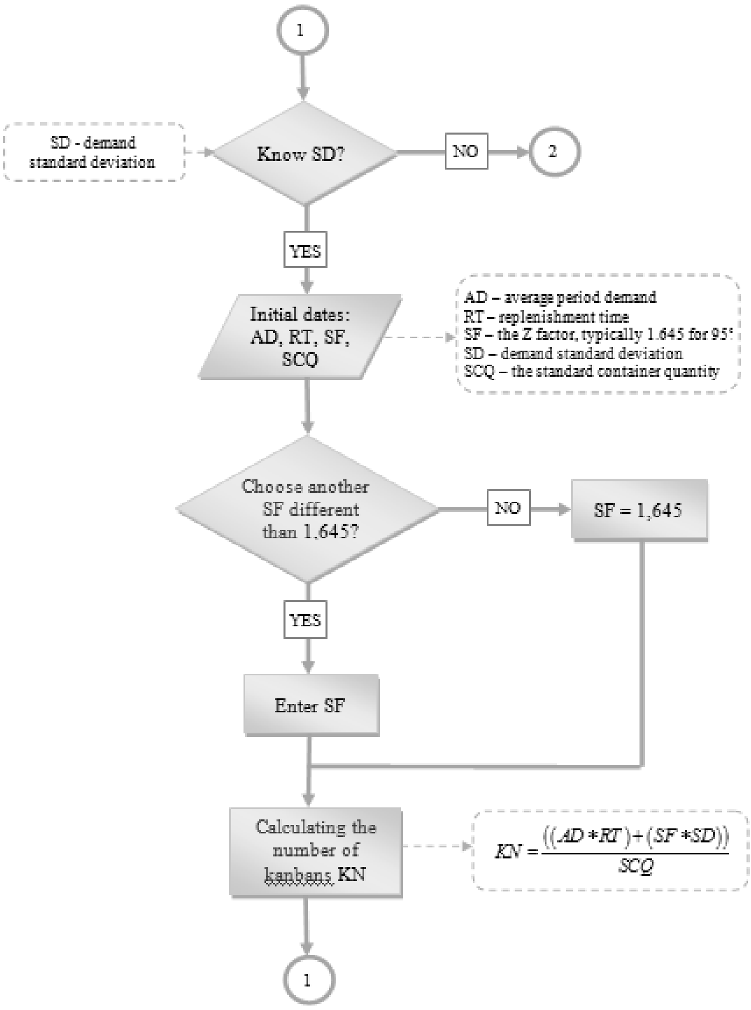

Fig.1. Kanban calculation algorithm

Such as we say before, in accordance with LEAN principles, the created value increase require activities and equipments, that needs to realise with the same or less funds, with high productivity, reaching the client expectation connected by the quality and reliability of acquisitionated product.

A synthetic indicator of this, regarding equipment performance is according to (Musat, 2007) the *synthetic efficiency* or *Overall Equipment Effectiveness* – OEE. This is also a mark for TPM programs.

To OEE calculation we take count by the *availability rate* (D), *performance rate* (R_p) and *quality rate* (R_c). According (Mobley, 2002) the OEE formula is:

$$OEE = D + R_p + R_c \quad (7)$$

where:
D – availability;
R_p – performance rate;
R_c – quality rate.

The equipment *availability* represents what percentaj from time production can be used, and the formula to calculate him is:

$$D = \frac{D_n - T_{nf}}{D_n} x100 \quad [\%] \quad (8)$$

where:
D_n – the required availability and represents the equipment maintenance time production, minus the planned downtime, such as: breaks, scheduled lapses, meeting, and so on;
T_{nf} – is the necessary real time in which the equipment is down for repairs or changeover

The goal for most companies is greater than 90 percent for availability.

The *performance rate* represents what percentaj from effective time is better used; is calculated with relation (8), as report betwen design cycle time (T_{cp}) for maintenance process multiplied by production (P), respectively time production (required availability).

$$R_p = \frac{T_{cp} xP}{D_n} x100 \quad [\%] \quad (9)$$

The performance rate is useful for spotting capacity reduction breakdowns. The goal for world-class companies is greater than 95 percent of OEE.

The *quality rate* represents the all existing equipments in process or in maintenance production cycle (N_p), minus number of quality defects (N_r), divided by the production input, and the formula for calculation is:

$$R_c = \frac{N_p - N_r}{N_p} x100 \quad [\%] \tag{10}$$

The formula is useful in spotting production-quality or maintenance problems, even when the customer accepts the poor-quality product. The goal for world-class companies is higher than 99 percent for availability.
Therefore, to be able to compete for the national total productive maintenance (TPM) prize in Japan, the equipment effectiveness must be grater than 85 percent.

$$OEE = 90\% x 95\% x 99\% = 85\% \tag{11}$$

Unfortunately, the equipment effectiveness in most Romanian companies is under 40-45 percent, and even US companies barely breaks 50 percent according to (Mobley, 2002).
If already exists all dates to calculate OEE, we can draw further the *Value Stream Map*, on his bases we can analyze manner in wich must be decoiling the activities.
LEAN indicators system may include:
- Existing stock value in production;
- Exhausting period for existing stocks;
- Total execution time for maintenance;
- Output time for first equipment from maintenance (lead time);
- Number of defects per million;
- Balanced Score Card;
- Stocks rotation.

The availability of equipment clearly indicates, according to the formula 7, their failure rate. The more equipment availability is smaller, the failure rate is higher (because the T_{nf} it increases) and therefore the probability of a repair that use parts from stock, increases.
Following the safety factor Sf is indirectly proportionate to the availability of equipments.
Equipment effectiveness and the quality rate are indicators of malfunction in normal parameters of the equipment. Therefore, logically, when the equipment effectiveness or quality rate has low values, logically the equipment will be stopped for repairs, so the stock of spare parts will be affected. Results:

SF~1/D
SF~1/R_p
SF~1/R_c

So:

$$SF \sim \frac{1}{D \times R_p \times R_c} = \frac{1}{OEE} \tag{12}$$

Therefore is proposed to introduce in the Kanban formula the safety factor SF, where

$$SF = \frac{1}{OEE} x100 \tag{13}$$

For an availability of 85%, similar to the Japanese industry, the safety factor SF is equal to 1.18. This value is introduced into the Kanban formula.

3. RESEARCH RESULTS

For the automatic calculation of SF factor, one have realised a program in Excel. In the corresponding input data fields, one introduces the known dates for equipment that uses the piece type (component) whose stock is analyzed and in the related cells are introduced formulas for availability, performance rate, quality rate, OEE and SF:

Input dates			
Item	Nr	Duration [min]	Total
Shift	2	480	=C3*B3
Breaks/shift	2	5	=B4*B3*C4
Meal break/shift	1	30	=B5*B3*C5
Time for defects		47	47
The design cycle		2.8 pieces/min	
No. total of pieces		2046	
No. of defect pieces		20	
No. of rework pieces		120	

Results	
Actual time available	=D3-D4-D5
Working time	=D14-D6
Equipment availability	=(D14-D6)/D14
Performance rate	=(C8/D15)/2.8
The quality rate	=(C8-C9-C10)/C8
O.E.E.	=D16*D17*D18
SF	=1/D19

Fig.2. Calculation model in the excel program of the safety factor SF

The obtained results are automatically illustrated in figure 3.

Input dates			
Item	Nr	Duration [min]	Total
Shift	2	480	960
Breaks/shift	2	5	20
Meal break/shift	1	30	60
Time for defects		47	47
The design cycle		2.8 pieces/min	
No. total of pieces		2046	
No. of defect pieces		20	
No. of rework pieces		120	

Results	
Actual time available	880
Working time	833
Equipment availability	94,7%
Performance rate	87,7%
The quality rate	93,2%
O.E.E.	77,4%
SF	1.29276

Fig. 3. An example for the safety factor SF calculation

This program can be used in the Excel for calculating the total efficiency of the equipment (OEE) and also to calculate the safety factor for all equipments that are submitted to the research. Based on this program, one can compose a database for the studied equipments. This factor SF is used as a safety factor in the Kanban calculating.

4. CONCLUSIONS

Analyzing the case study results compared with world-class level performances, as well as the advantage of LEAN strategy implementation even in maintenance activities, we can get to the following conclusions:

1. Overall Equipment Effectiveness (OEE) is influenced and determinated in the major measure by the equipment availability, the one who assure the realization of an major total productivity during the time operations;
2. OEE can constitute an important indicator in performance evaluation of an efficient activities, technological equipment and even of an service made by customer;
3. In conditions of an constant consecvent and enought large net availability run time, the equipment availability depends in major measure by the actual operating time and indirectly by the downtime losses: breakdowns, setups, adjustments, etc.; this one makes that the maintenance (preventive and corrective) can have a positive impact on any company`s productivity and profitability, as long as the entire organization is willing to change its culture and the way in wich day-to-day business is conducted.
4. In fact even if the equipment is in working order but the effectiveness or quality of the parts is inconsistent, there is obviously a tendency to stop and fix it, so obviously this will affect the stock of spare parts.

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