Int. J. Nonlinear Anal. Appl. 13 (2022) No. 1, 321–342
ISSN: 2008-6822 (electronic)
http://dx.doi.org/10.22075/ijnaa.2022.5499

Optimization of process parameter involved in the effectiveness evaluation of continuous line manufacturing system (CLMS)

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(Communicated by Madjid Eshaghi Gordji)

Abstract

To sustain in the global competitive market, the manufacturing organizations are adopting tools like Total Productive Maintenance (TPM), Lean Manufacturing (LM), etc. Implementation of these tools was assessed by an effectiveness index called Overall Equipment Effectiveness (OEE) Throughput Effectiveness (TE). Overall Manufacturing Line Effectiveness (OMLE) used as the performance evaluation index for the integrated tool [Total Productive Lean Manufacturing –TPLM] implementation performance has been assessed. OMLE is a robust metric of manufacturing performance that incorporates the measures like Line Availability (LA), Line Production Quality Performance (LPQP) of the product line. OMLE offers a means of controlling the whole production process by analyzing results from the totality of events with or without inventory between the processes in the product line. In the present paper, the attempt made towards identifying the bottleneck parameter (Losses in the processes –category A, the Cycle time in the processes-category B, Inventory between the process – category C) in the bottleneck processes of the n number of the processes product line through programming (software in C). Also, the top three parameters of the processes in the n process product line have been obtained easily towards executing improvements by the engineers and managers. Analyze it with the change of inventory and zero inventory between the five, seven, and nine different processes product line processes. The suggested improvement activities (obtained from the OMLE evaluation and optimization program) are validated in south India's real case study organization and improved the bottleneck processes and losses in the product line.

Keywords: Performance Evaluation, Bottleneck parameter, World Class Manufacturing, Manufacturing System Analysis, Manufacturing management.

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Received: August 2021 *Accepted:* September 2021

1. introduction

In the continuous line manufacturing system (CLMS) shown in figure 1, the product moves continuously [4]. The number of processes in the product line varies based on the type of product and the type of customer. From figure -1, the defective pieces found after manufacturing in any product line processes will not move to the next stage. The inventory stored in between the processes of the product line has also been considered in the effectiveness evaluation [6]. For the CLMS,

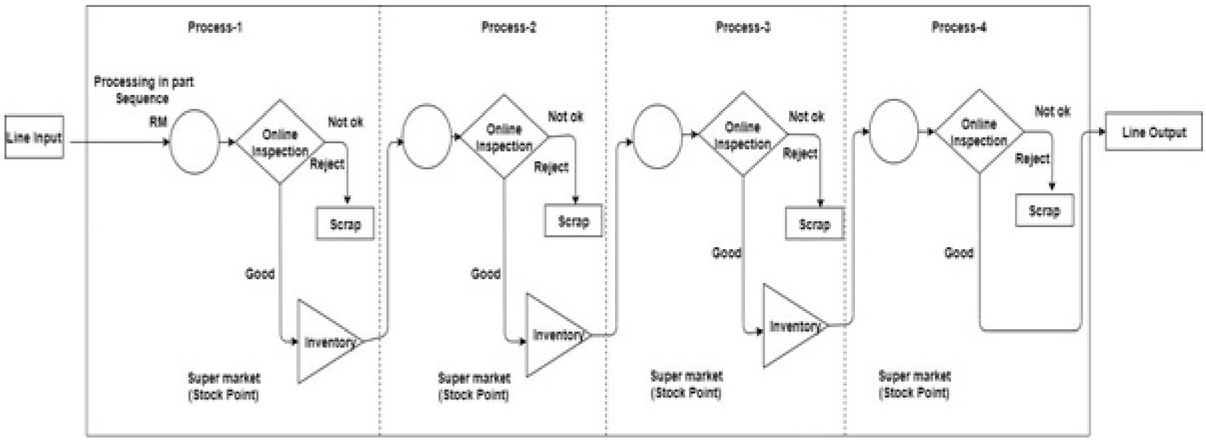


Figure 1: Continuous product line manufacturing system with inventory between processes of 4 process product

the performance of the manufacturing evaluated in line with the extension of Overall Equipment Effectiveness (OEE) to Overall Line Effectiveness (OLE), then to Overall Equipment Effectiveness on the Manufacturing Line (OEEML) then Overall Manufacturing Line Effectiveness (OMLE) has been established from the OLE on need-based modification. OEEML [5] and OMLE [12] suggested a new method of evaluating the product line with inventory between the processes in the product line. Establishment of OMLE with the extension of OLE and far better (realistic) than OEEML. The losses associated with the OMLE given in figure-2. The figure-2 is an extension of six big losses suggested by [16]. The six big losses are equipment failure, setup and adjustment, idling and minor stoppage, reduced speed, defect, and reduced yield. The additional two losses towards evaluating effectiveness through OMLE are line management loss (want of resources) and line organizational loss (mismatch of cycle time between the processes). WCM tools (TPM, LM) address these losses.

As suggested by [8], these indexes do not only act as a monitoring mechanism but also consider process improvement in iterative optimization of individual processes in the product line. It also pays a way for adopting a systematic /continuous method of execution improvement in the specific bottleneck process, losses/parameters (availability, performance associated quality), and reaches the target with reasonable time [3],[22]. It is an indicator of process cycle time improvement and as an approach to achieve it. Various researchers used it to assess the improvement (before and after - kaizen/countermeasures) of a process in the manufacturing environment.

[2] highlighted that these indexes act as a driver for improving a business's performance by concentrating on quality, production machine utilization, and non-value-added activities in the manufacturing processes.

In this paper, a computer software optimization package developed to calculate OMLE of a product line consists of the 'n' number of the process run for 'N' number of days planned towards meet the customer requirement (quantity of good pieces required). The top three bottleneck processes, losses/parameters towards executing improvement in the product line are highlighted. Based on the

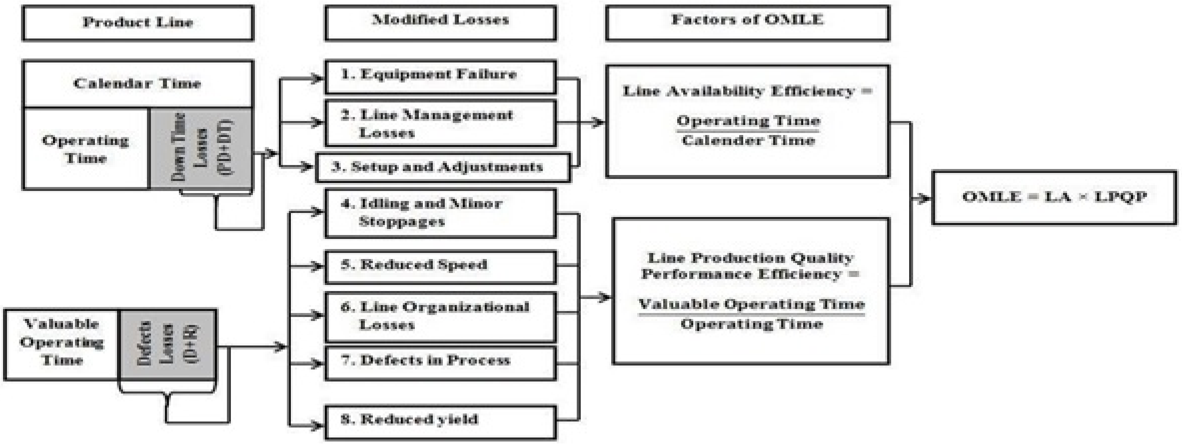
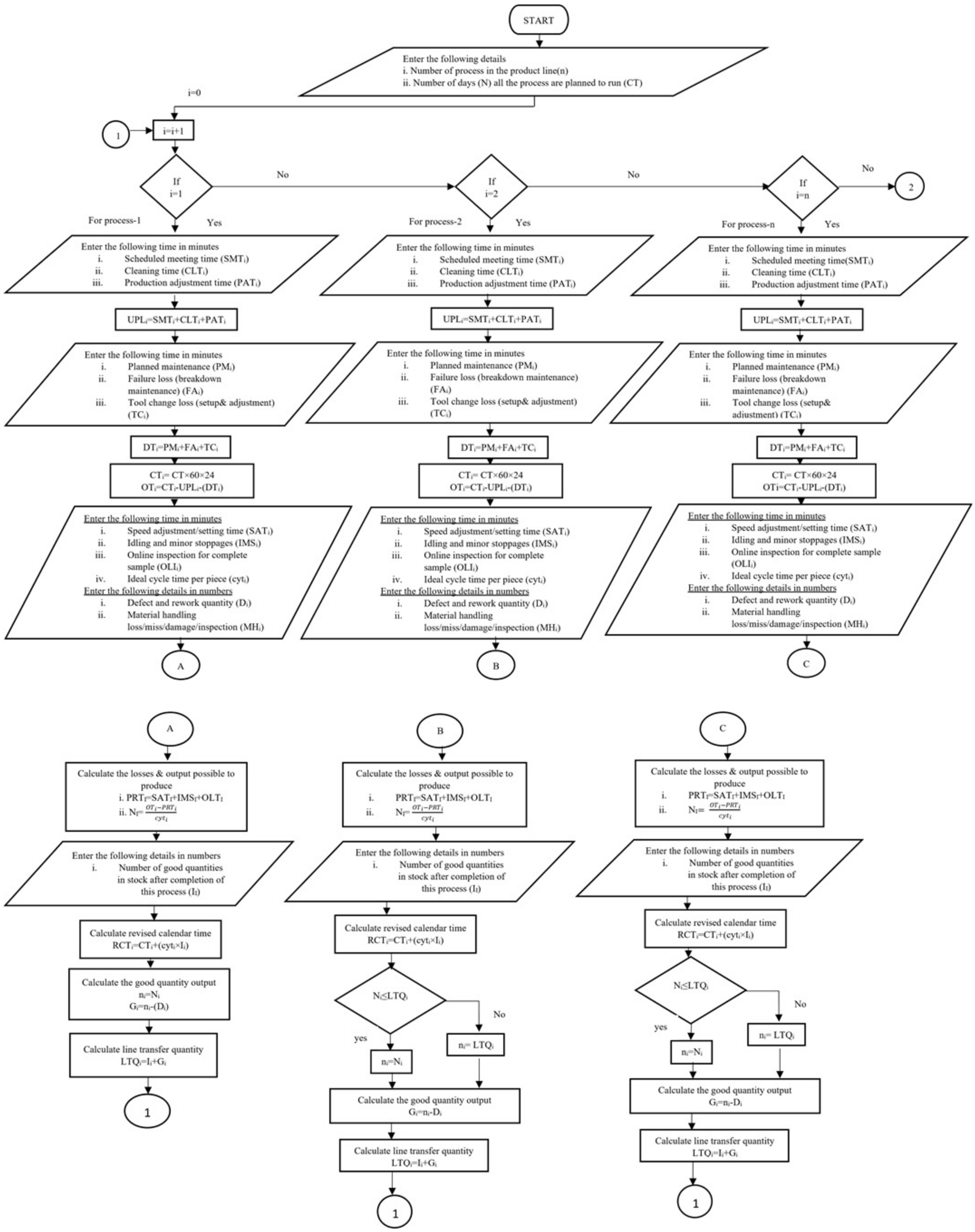


Figure 2: OMLE evaluation with its associated losses

feasibility among these three options (for the number of good pieces required from the product line to meet customer demand), the engineers in the product line can execute the improvement on it and estimate the effectiveness (OMLE) of the product line. For easy understanding, 5/7/9 processes in the product line were taken as case studies towards OMLE assessment, analysis, and execution of improvements (through validation) on the bottleneck parameters in chapters 2, 3, and 4, respectively.

2. Assessing the effectiveness of the CLMS

The effectiveness of the product line consisting of the 'n' number of the process evaluated using the step-by-step methodology based on the number of processes in the product line as given in figure 3. The OMLE evaluation flow chart has been similar and extension of effectiveness evaluation index OLE [15]. By visualizing the flow chart, everyone would understand the evaluation of index OMLE and its contributing parameters like Line Availability (LA) and Line Production Quality Performance (LPQP). It will also be a general flow chart for any number of processes in the product line. The program will read the input data, do the calculation for the first process, and then move to the following processes in the product line.


START
Enter the following details
i. Number of process in the product line(n)
ii. Number of days (N) all the process are planned to run (CT)
i=0
i=i+1
If i=1
No
If i=2
No
If i=n
No
For process-1
Yes
For process-2
For process-n
Enter the following time in minutes
i. Scheduled meeting time (SMT$_i$)
ii. Cleaning time (CLT$_i$)
iii. Production adjustment time (PAT$_i$)
UPL$_i$=SMT$_i$+CLT$_i$+PAT$_i$
Enter the following time in minutes
i. Planned maintenance (PM$_i$)
ii. Failure loss (breakdown maintenance) (FA$_i$)
iii. Tool change loss (setup& adjustment) (TC$_i$)
DT$_i$=PM$_i$+FA$_i$+TC$_i$
CT$_i$= CT×60×24
OT$_i$=CT$_i$-UPL$_i$-(DT$_i$)
Enter the following time in minutes
i. Speed adjustment/setting time (SAT$_i$)
ii. Idling and minor stoppages (IMS$_i$)
iii. Online inspection for complete sample (OLI$_i$)
iv. Ideal cycle time per piece (cyt$_i$)
Enter the following details in numbers
i. Defect and rework quantity (D$_i$)
ii. Material handling loss/miss/damage/inspection (MH$_i$)
A
B
C
Calculate the losses & output possible to produce
i. PRT$_I$=SAT$_I$+IMS$_I$+OLT$_I$
ii. N$_I$= $\frac{OT_i-PRT_i}{cyt_i}$
Enter the following details in numbers
i. Number of good quantities in stock after completion of this process (I$_I$)
Calculate revised calendar time
RCT$_i$=CT$_i$+(cyt$_i$×I$_i$)
Calculate the good quantity output
n$_i$=N$_i$
G$_i$=n$_i$-(D$_i$)
Calculate line transfer quantity
LTQ$_i$=I$_i$+G$_i$
1
N$_i$≤LTQ$_i$
yes
No
n$_i$=N$_i$
n$_i$= LTQ$_i$
Calculate the good quantity output
G$_i$=n$_i$-D$_i$
2

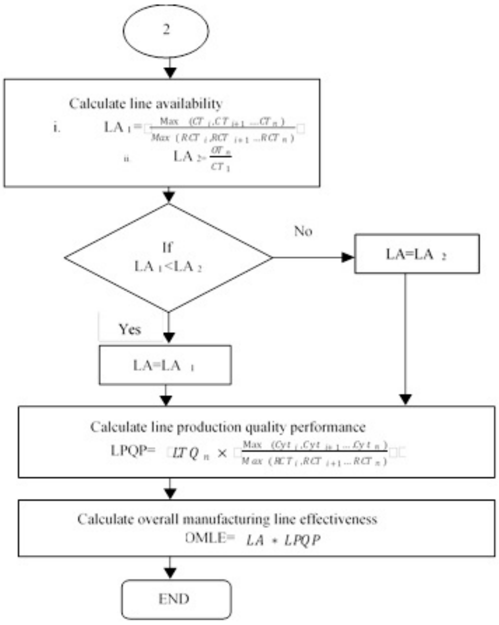


Figure 3: OMLE Assessment (current state evaluation) flow chart

3. OMLE Analysis and Improvement

The ultimate goal of effectiveness is to meet the customer's requirement economically. For that purpose, it is necessary to increase unit time output and reduce the expenses (i.e., losses) arising from the wasteful use of materials. It is not possible to assign random values (based on experience and data secondary data) as done by [15], towards allocating input data (losses) towards various processes in the product line (OLE estimation). So it is impossible to judge that OMLE reduction is only because of either loss related to LA or losses associated with LPQP, i.e., not likely to generalize the LA is contributing more based on the number of trails as done in the OLE estimation. There are cases in which failures and minor stoppages often occur, deteriorating the equipment operating rate. There are also cases in which frequent setup adversely affects the operating speed.

For easy understanding, it is grouped as a category –A, Category -B, Category- C related losses towards reduction of OMLE. In a CLMS, the parameter related to each process (Category-A listed parameters towards the losses of resources - machine, method (handling) and man; Category-B listed parameters towards ideal cycle time) related to each process in the product line and inventory between the processes (Category –C listed parameters towards inventory (WIP)) are playing a significant role in the performance index of OMLE evaluation system. The most important thing is that the index has been affected by the bottleneck parameter (categories –A, B, C) and the bottleneck process. So, balancing the manufacturing line aimed towards the distribution of task over the various processes involved in the product manufacturing line [17] with improvement on reduction of losses in categories – A, B, C. Therefore, the improvement has been carried out in single level and combined level. The combined level consists of 2 combinations of any three categories A, B, C as (A&B, A&C, B&C) and three combinations of all the three categories A, B, C (A&B&C).

Table 1: Loss reduction / Improvement methodology

S. No.	Losses [14]	Description	Improvement methods [10]
1	Equipment Failure	Losses due to failures. Types of failures include sporadic function stopping failures and function reduction failures in which the function of the equipment drops below normal levels	• Classification of failures (based on occurrence, failure mode, recurrence, causes – deterioration, skill shortage, insufficiency of basic conditions, defective design) • Failure analysis (Investigation of causes, pursuit of causes, countermeasure, preventive measures) and Observance of conditions of use & Preparation of basic conditions (Cleaning, Oiling, Tightening) • Rectification of deterioration & Improvement of design shortcomings, Improvement of operational / maintenance skills
2	Management	Waiting time caused because of want of materials, tools towards execution of conversion process	• Identifying the resources requirement, study, and analysis • Optimisation & Standardisation
3	Setup and adjustment	Stoppage losses that accompany setup changeovers	• separation of external setup and internal setup. • Shifting internal setup to external setup (pre-setting, one-touch arrangement, no adjustment, intermediary jigs). and study of the internal setup method and time reduction (fitting method study, execution of parallel work, work-sharing) • Elimination of adjustment to the extent possible
4	Idling and Minor stoppage	When the equipment temporarily stops or idles due to sensor actuation or jamming of the work. The equipment will operate normally through simple measures (removal of the work. Resetting)	• Correction of minor defects (external appearance –flaws, dimensions - clearance, operations – backlash), Thorough Observance of basic principles at workshops (cleaning, oiling-stains, tightening), and study of optimal conditions (fitting conditions – angle, processing conditions – optimum feeding volume) • Research on shortcomings (a design that is appropriate to shapes of parts, study of mechanism)
5	Reduced Speed	Losses due to actual operating speed falling below the designed speed of the equipment	• Comprehending real causes (vibration, sound change during cutting) • Checking the effectiveness of actions (shortening air cut time, shortening the idle time between actions, accelerating action timings – execution of sequential activity into parallel activity)
6	Line organization	Idle time losses when waiting for multiple processes or multiple platforms	• Measuring rapid/slow transverse time (handling loss) • Online inspection wastage reduction, Man, machine balancing, Reassessing the order of processes in the product line
7	Defect and rework	Losses due to the defect and reworking / reprocessing	• Stratification of defect phenomenon Study of mechanisms & factor analysis • Preparation of countermeasures, Confirmation of results, Implementation of PM analysis pursuit of ideal states, Exposure of defects and countermeasures
8	Startup & Yield	Losses arise due to differences in the weight of the input material and the weight of the quality products.	• Investigation of related equipment and its surrounding • Measurement of the amount of waste, Countermeasures, and standardization

3.1. Single level improvement

3.1.1. Losses reduction (Category-A)

The eight losses (as given in figure 2) will not occur in all the equipment/processes in the product line. Their occurrence varies depending on equipment characteristics, product characteristics, type of operator employed, operating condition, type of raw material used, and equipment control levels. It is not possible to assign random values as done by [15] based on the experience in the product line. It is necessary to start examining the loss structure to perceive the seriousness of the loss concerned. Therefore, the first part design to quantitatively reveal the 7 top losses (as in table-2) that impede the inherent capacity of the equipment, so the degree of their contribution rate and the priority order of countermeasures can be classified. As option-1, option-2, option-3 for the bottleneck process identification in the product line. Based on the literature survey, improvement should start with project activities having major effects or easy to tackle (easy for implementation time, effort and cost). Similarly, a follow-up study must conduct regarding how the losses changed over time, whether improvements are making significant contributions, and if other problems have arisen—the ways of reducing the major losses given below (table-2). For the n process product line, the sequence of loss reduction phenomenon (under Category-A classified parameter) listed in the figure-4.

Figure-4 is self-explanatory, so the researcher can easily understand the procedure for improving the losses related to the process's nonavailability during the planned production period. By executing the improvements on category-A associated parameters, OMLE improved. The kaizen adopted towards reducing category A contributing parameter associated with each process in the product line depends on the type of product lines. In computer programming, the reduction of losses under each process executes with a minimum of 10% to a maximum of 90 %. Under category A for the unplanned down time parameter, associated losses are scheduled meeting time-SMT, cleaning time-CLT, production adjustment time – PAT and for the down tile parameter, losses are planned maintenance – PM, Failure / Breakdown maintenance –FA, Tool change loss/setup and adjustment (TC). The detailed description and improvement of each loss are separately given in table-2. The improvement in the line has been sequentially carried out (iteration by iteration with changes in the reduction percentage with the slab of 10% from the minimum [efforts/time period /cost in kaizen] 10% to maximum [efforts/time period /cost in kaizen] of 90%) based on the feasibility for the type of product line. The improvements execute with a maximum of four stages (stage-1 to stage-4).

In stage-1, the improvement has been executed in the single /top bottleneck parameter with its associated losses and the respective bottleneck process. The improvement has been assessed based on the improved OMLE value for the current state OMLE value of the product line. It has been checked for all the processes (1 to n) / parameter/losses in the product line consist of n processes. Based on the level of improvement (compared with the current state / initial assessment) achieved in OMLE under various processes/parameter/losses, it has been displayed as different alternatives, among that top three has been visualized (from the program output) to the engineers in the product line towards executing improvement if the organization can perform the improvement at what level (process/parameter/losses) then engineers can choose the best option among the top three alternatives towards getter better or improved OMLE.

The improvement loop continues to the next stage (stage-2) of executing the improvement (through kaizen on the bottleneck process/parameter/losses) simultaneously in two processes/parameter losses and asses the OMLE of the complete product line. If there is a positive change (by adopting KAIZEN) in the OMLE compared with the stage-1 improvement, it has been considered. The corresponding contributing processes/parameters/losses are noted. The better OMLE (compare with single-stage) values and its options are also generated and visualizing maximum of top four options only.

Similarly, the improvement loop continues to the next stage (stage-3,4) for executing the improvement (through kaizen on the bottleneck process/parameter/losses) simultaneously in three, four processes/parameter losses and asses the OMLE of the complete product line. If there is a positive change (by adopting KAIZEN) in the OMLE compared with the stage-2 and stage 3 improvement, it has been considered. The corresponding contributing processes/parameters/losses are noted. Because of practical feasibility maximum of four steps (stage-1 to stage-4) of improvement have been programmed in the n process product line. Here, stage-4 means not indicating four different numbers of processes in the product line. It may be of four different parameters/losses in the same processes itself. It will highlight only the top losses and their associated processes in the n process product line. Finally, the higher OMLE and its associated improvement parameters/processes/losses in stages one/two/three/four have been chosen to execute improvement. This OMLE has been named OMLEA.

3.1.2. Cycle time reduction (Category –B)

For over a decade, there has been an increasing intent in the engineers and more responsive operations and the reduction in the cycle time to improve performance across the entire product line. Prof. TOM Luyster (LM – expert from standard manufacturing inc, US) adoption of the tools and techniques like Just in Time (JIT), LM, Single Minute Exchange of Dies (SMED) aimed that there are advantages and benefits associated with their efforts to control manufacturing lead time (value addition – cycle time and non-value addition time). Cycle time reduction is one of the performance index parameters for the industry adopting the LM tool. Cycle time reduction will lead the customer to obtain /fulfill their requirements in a shorter span of time [1]. As engineers focused on the processes in the product line by identifying the waste (non-value-added like unnecessary operations, over-processing, fatigue, and layout) and prepare action plans towards Eliminate, Combine, Reduce, and Standardise or Simplify [ECRS] [9]. By concentrating only on the cycle time of individual processes will also pay a way to increase the work in progress (WIP) inventory between processes in the product line. But the OMLE index will consider the cycle time and the WIP between the processes in the product line, so fixing OMLE is a good yardstick towards asses the improvements and do benchmark also. The sub tools used towards reducing cycle time are POKA YOKE, Kaizen, Visual control, Simplification, Standardization [19]. In short, to maintain a continuous flow between the processes in the product line and to meet the target (TAKT rate), cycle time reduction is essential [13]. The ways of reducing it have been given in Table 2.

Table 2: Cycle time reduction methodology

Stages	***Activity***	***Improvement methods***
1	***The actual measurement of the cycle time chart***	***• Measuring the cycle time of each motion. • Considering the measuring method so the figure in the first decimal places can be learned. • Comparing it with the total cycle time chart at the design stage.***
2	***Shortening of cycle time***	***• Clarify the existence/non-existence of idle time between motions • Studying the effectiveness of motions • Studying compound tools • Working out plans for shortening the gap • Feasibility of shortening the time using vibration measurement • Reassessing the order of operation within the process • Reassessing the conditions of machines and run them with optimal conditions. • Studying the thermal capacity and comparing it with the theoretical value***

The sequence of the procedure illustrated in category-A loss reduction, Category –B cycle time reduction for individual processes in the product line, is shown in figure-5. The programming has been executed in the n process product line. The cycle time corresponding to each process has been sequentially reduced (iteration by iteration with changes in the reduction percentage with the slab of 05% from the minimum [efforts/time period /cost in kaizen] of 10% to maximum [efforts/time period /cost in kaizen] of 90%) based on the feasibility for the type of product line. The improvements have been executed a maximum of four stages (stage-1 to stage-4).

In stage-1, the improvements have been executed in any process (from process-1 to process-n) of the n process product line. Based on the level of progress achieved in OMLE (compared with the current state / initial assessment) under cycle time reduction in the processes, it has been displayed from the developed program as different alternatives/options, among that top three has been visualized to the engineers in the product line towards executing improvement. Suppose the organization can execute the improvement in the corresponding processes cycle time. In that case, engineers can choose the best option among the top three alternatives towards better or improved OMLE. Reduction in cycle time through the kaizen (layout change/machine modification/methodology change) executed in a single process under stage-1 has been extended in any two/three/four processes in the n process product line under stage-2, stage-3, and stage-4. Under each improvement stage, the alternatives have been tabulated, with improvements (process and the percentage of reduction in cycle time) being carried out. Among the four stages with the alternatives, the best OMLE value has been chosen and termed as OMLEIB. This OMLE is the best OMLE towards executing improvements achieved by cycle time reduction in the respective processes belong to the product line. Because of practical feasibility maximum of four stages (stage-1 to stage-4) of improvement have been programmed in the n process product line because of practical feasibility. Here a maximum of 4 processes cycle time has been reduced in the n number of processes product line. The percentage of reduction in the individual process is from 10 to 90.

3.1.3. Inventory Optimization (Category C)

Increasing globalization has tended to longer manufacturing lead time, which by conventional inventory control theory results in greater inventory levels to provide a similar performance [20] towards maintaining customer schedule adherence. This stock (WIP) has been referred to as safety stock, with the amount of this stock increasing in a square root relationship to the lead time [18]. [7] listed that increase in inventory is a risk mitigation approach. [11] particularly emphasizes the role of inventory in the situation of uncertainty in the process line. Whereas LM thought inventory had been categorized in seven waste, reducing it as much as possible.

LM says the best batch size of the product being manufacturing in the product line is single [21]. The goal of traditional inventory control theory has oriented towards controlling, optimizing inventory quantity.

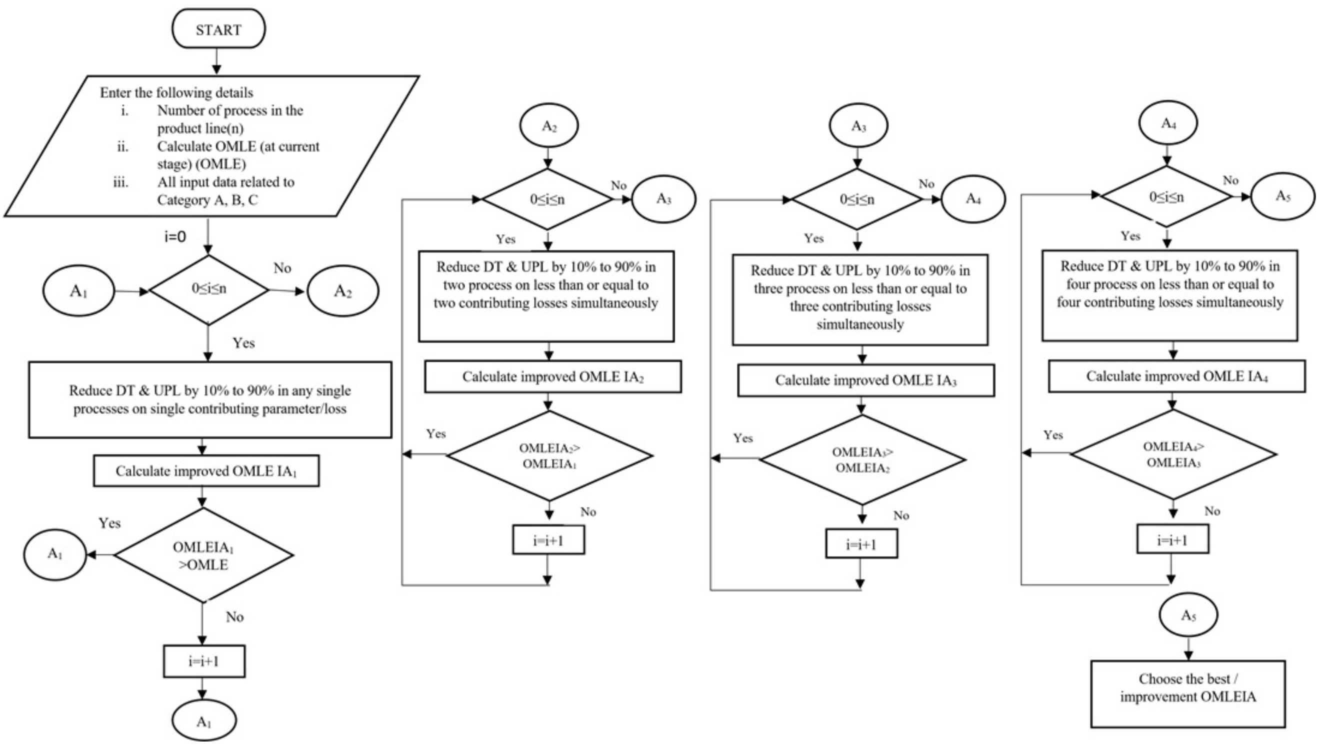


Figure 4: Category-A (loss) reduction flow diagram

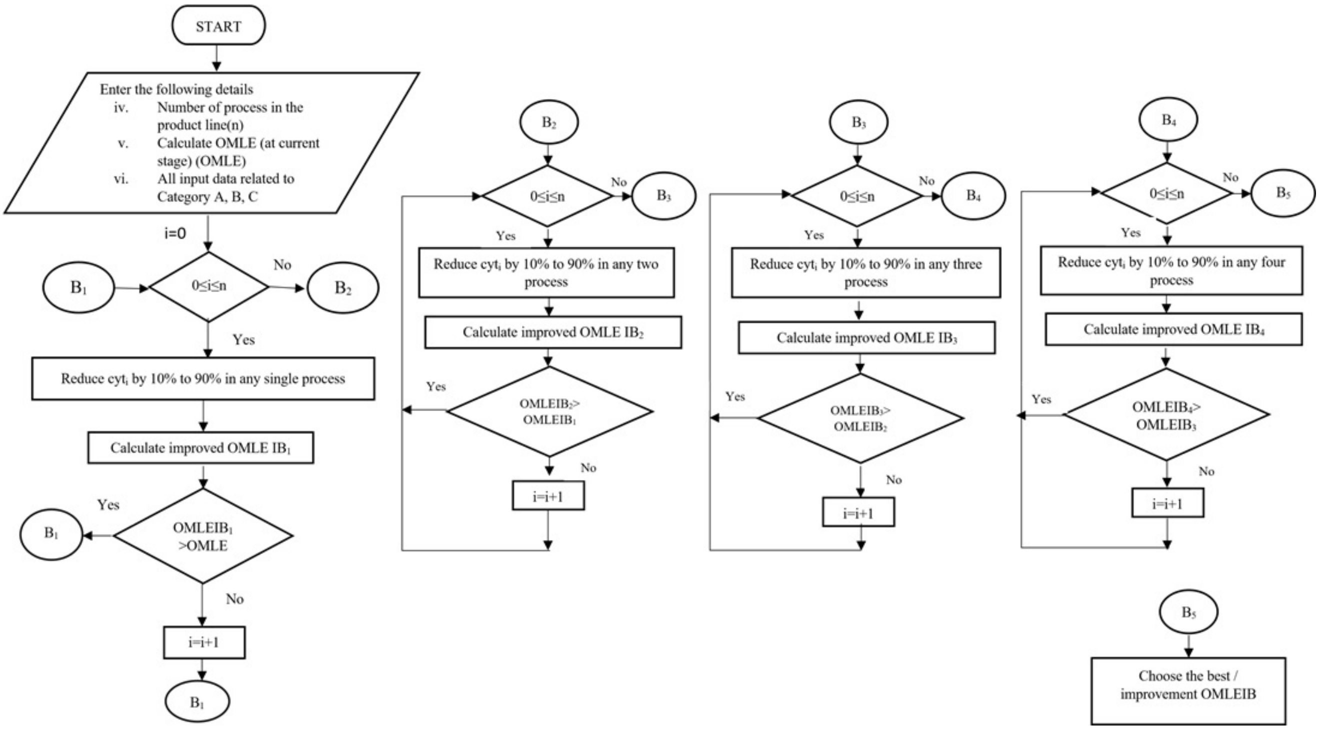


Figure 5: category-B (Cycle time reduction) flow diagram

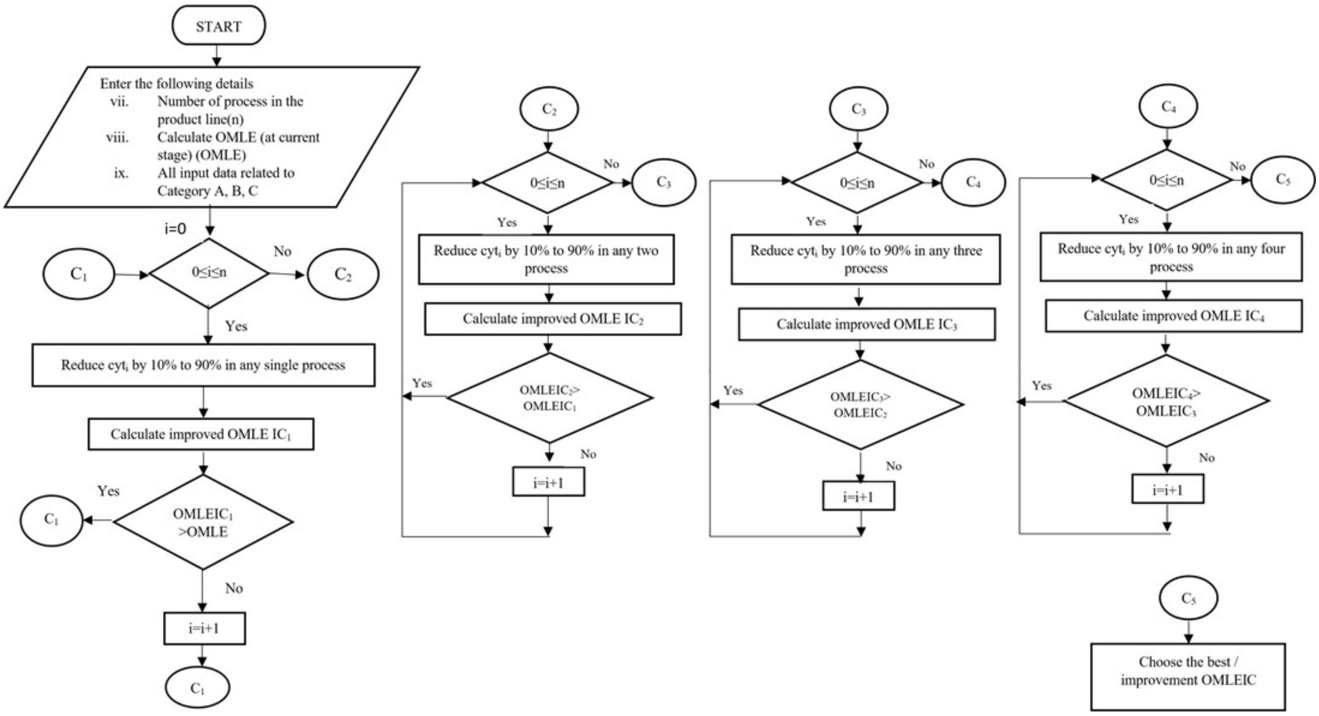


Figure 6: category-C (inventory between process optimization) flow diagram

In contrast, the goal is relevant, and recent think with the application of WCM highlighted more on the minimization of inventory levels or NIL inventory. Compare with both. The approach leads to maintain optimum inventory (WIP) in the product line at the necessary points (between the processes) in the manufacturing line. Figure-6 shows the OMLE improvement methodology by optimizing the inventory between the processes in the product line. Compare with category – A & B (as in figure-4 & 5 respectively) about the OMLE improvement with reduction of contributing parameters, here (in figure-6) both the inventory reduction and inventory increase in between the processes of the n process product line has been considered. The inventory (good pieces stocked –work in progress after the end of each process) has been sequentially varied (iteration by iteration with changes in percentage with the slab of 10% from the maximum [efforts/time period /cost in kaizen] of 90% reduction in inventory quantity to a minimum [efforts/time period /cost in kaizen] of 30% increase in inventory quantity from current stock) based on the feasibility of possibility at the end of each process in the product line. The suggested improvements have been executed with a maximum of four stages (stage-1 to stage-4).

In stage-1, the improvements have been executed at the end of any process (from process-1 to process-n) in the n process product line. Based on the level of progress achieved in OMLE (compared with the current state / initial assessment) under inventory variation (either increase or reduce) at the end of the processes, it has been displayed as different alternatives/options, among that top three has been visualized to the engineers in the product line towards executing improvement. Suppose the organization is able to execute the improvement at the end of the corresponding processes inventory. In that case, engineers can choose the best option among the top three alternatives towards better or improved OMLE.

In stage-2, the improvement (inventory variation) has been carried out at the end of any two processes in the n process product line. Similarly, it has been extended up to stage-4 with the maximum of inventory changes at the end of any four processes in the n process product line. Under each of the four stages, the OMLE has been displayed (after executing this improvement program) with alternative options towards an easy way of improving the engineers. During the changes of inventory, the OMLE value either reduce or maintain as such, then the corresponding modifications in inventory has not been considered for further analysis, and the improvement loop jumped towards the following stages and proceeded towards the next iteration with changes in inventory quantity lies (good piece stock) at the end of the next processes.

Because of practical feasibility maximum of four stages (stage-1 to stage-4) of improvement have been programmed in the n process product line because of practical feasibility. The best (higher) OMLE value has been noted under each stage, among the various OMLE values, the best OMLE (as OMLEIC) and its corresponding inventory (either increase or reduce) with the percentage of changes have been selected for further analysis and action. From the single level, OMLE improvement either Category-A or Category-B or category-C under four stages are not enough towards meeting the organization/customer requirement then the organization needs to move to the next level of improvement, i.e., combined level, in which address the categories simultaneous or in a sequential manner.

3.2. Combined level of improvement (2 or 3 combinations)

From the figure-7, it has been referred that the OMLE obtain from the best of each category – A (from figure-4), category – B (from figure-5), category – C (from figure-6) have further been improved by combining it as two levels of categories (A with B, B with C & A with C) and three levels of categories (A with B with C, i.e., AB from two levels with C). In this simulation system, because of practical difficulty, programming complexity, execution time, the alternative options under each stage have not been listed. Only the best option under each stage with a maximum of four stages (stage-1 to stage-4) of improvement has been programmed in the n process product line.

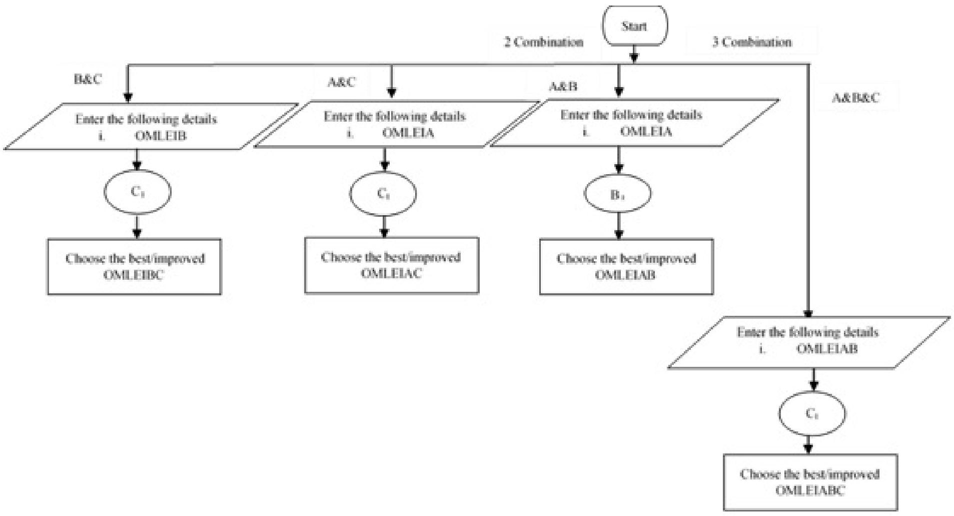


Figure 7: Category-A, B&C combined stage of improvement

3.2.1. A&B (Two category combination)

The best option of Category –A (either one, or two, or three, or four process improvement - parameter/losses) has been chosen as the current state .i.e., the corresponding process, losses related to OMLEIA are considered as a current state towards executing improvement further by combining it with Category-B. Now the (Category –B) cycle time for each process in the product line has been sequentially reduced (iteration by iteration with changes in the reduction percentage with the slab of 5% from the minimum [efforts/time period /cost in kaizen] of 10% to maximum [efforts/time period /cost in kaizen] of 90%) based on the feasibility for the type of product line. The improvements (cycle time reduction) have been executed with a maximum of four stages (stage-1 to stage-4). In stage-1, the improvements have been executed in any process (from process-1 to process-n) of the n process product line. Based on the level of improvement achieved in OMLE (compared with the current state / initial assessment) under cycle time reduction in the processes, it has been analyzed and displayed the best option (improved OMLE) as OMLEIAB. This OMLEIAB is the best OMLE towards executing improvements achieved by merging category A with category B and implement the suggestion in the respective processes belong to the product line.

3.2.2. A & C (Two category combination)

The best option of Category –A (either one, or two, or three, or four process improvement - parameter/losses) has been chosen as the current state .i.e., the corresponding process, losses related to OMLEIA are considered as a current state towards executing improvement further by combining it with Category-C. Now the (Category –C) inventory at the end of each process in the product line has been sequentially varied (iteration by iteration with changes in the slab of 10% from the maximum [efforts/time period /cost in kaizen] of 90% reduction to a minimum [efforts/time period /cost in kaizen] of 30% improvement from current stock) based on the feasibility for the type of product line. The improvements (inventory quantity variation between processes) have been executed a maximum of four stages (stage-1 to stage-4).

In all the stages (stage-1 to stage-4), the improvement (inventory variation) has been carried out at the end of any single process to four processes in the n process product line. The improvement loop jumped towards different stages and proceeded towards different iterations with inventory quantity changes (good piece stock) at the end of each process. The best (higher) OMLE value has been noted under each stage. Among the various OMLE values, the best OMLE (as OMLEIAC) and its corresponding inventory (either increase or reduce) with the percentage of changes have been selected for further analysis and action. This OMLEIAC is the best OMLE towards executing improvements achieved by merging category-A with category-C and implement the suggestion in the respective processes belong to the product line.

3.2.3. B&C (Two category combination)

The best option of Category –B (either one, or two, or three, or four process cycle time reduction has been chosen as the current state towards executing improvement further by combining it with Category-C. Now the (Category –C) inventory at the end of each process in the product line has been sequentially varied (iteration by iteration with changes in the slab of 10% from the maximum [efforts/time period /cost in kaizen] of 90% reduction to the minimum [efforts/time period /cost in kaizen] of 30% improvement from current stock) based on the feasibility with respect to the type of product line. The improvements have been executed a maximum of four stages (stage-1 to stage-4). In all the stages (stage-1 to stage-4), the improvement (inventory variation) has been carried out at the end of any single process to four processes in the n process product line. The improvement loop jumped towards different stages and proceeded towards different iterations with inventory quantity changes (good piece stock) at the end of each process. Among the obtained improved OMLE (in different iteration), the higher OMLE value has been chosen as the best OMLE (OMLEIBC) towards executing improvements achieved by merging Category-B with category-C and execute the suggestion in the respective processes belong to the product line .

3.2.4. $A, B\&C$ (Three category combination)

From the two-category combination of $A\&B$, the best option of Category –A&B (either one, or two, or three, or four process improvement - parameter/losses/cycle time) has been chosen as the current state .i.e., the corresponding process, losses, cycle time related to OMLEIAB are considered as a current state towards executing improvement further by combining it with Category-C. Now the (Category –C) inventory at the end of each process in the product line has been sequentially varied (iteration by iteration with changes in the slab of 10% from the maximum [efforts/time period /cost in kaizen] of 90% reduction to a minimum [efforts/time period /cost in kaizen] of 30% improvement from current stock) based on the feasibility with respect to the type of processes and the WIP in the product line. The improvements have been executed with a maximum of four stages (stage-1 to stage-4). In all the stages (stage-1 to stage-4), the improvement (inventory variation) has been carried out at the end of any single process to four processes in the n process product line. The improvement loop jumped towards different stages and proceeded towards various iterations with inventory quantity changes (good piece stock) at the end of each process. Among the obtained improved OMLE (in different iteration), the higher OMLE value has been chosen as the best OMLE (OMLEIABC) to execute improvements achieved by merging Category-AB with Category-C and implementing the suggestion in the respective processes belong to the product line.

4. Result and discussion

OMLE is an effective tool to benchmark, analyse, and improve the production process with n number of processes in the CLMS. OMLE measures inefficiencies in the line and groups them into line availability, line production performance quality to help analyse the bottleneck machine and have a better understanding of all the processes in the product line. OMLE may also be considered as a company's performance and provide indicators of where their performance should be improved in the future. OMLE analysing software package is a user-friendly, reliable index for all types of products being manufactured under CLMS. The evaluation (step by step) methodology towards OMLE has been given (figure 4, 5, and figure 6), and it has been validated with the actual case studies. The effectiveness evaluation and highlighted improvement (to be carried out) with options in the developed software package (program) written in C language. To understand the evaluation system in-depth, three different cases (numerical data) of manufacturing lines with three different numbers of processes in each case. The three different case studies that have been taken are case-1: 5 different processes (lift bracket manufacturing), case-2: 7 different processes (pressure cooker manufacturing), case-3: 9 different processes (compressor wheel) product line are given in figure -8, figure-9 and in figure -10 respectively. The value/input data for each parameter/row are entered manually (real production datasheet from the product manufacturing line). For category-A, nine different parameters/losses for each process in the five-process product line are shown in figure 8. For category-A, nine different parameters/losses for each process in the seven-process product line are shown in figure 9. For category-A, nine different parameters/losses for each process in the nine-process product line are shown in figure 10. If any losses/parameter is not present / not available, then it has been entered as 0 (zero) for the concerned processes in the product line (for e.g., in figure -8, towards five processes product line - process-1, the failure loss, the minor stoppage loss, the defect and rework loss are NIL / Not available, so it has been entered as 0). Similarly, it has been continued for all the processes and all the categories (A, B, C) in the product line. The data are entered based on a unit of measures given with respect to each category (each row), parameter/losses. In general, the time-related data are entered in terms of minutes; quantity-related data are entered in terms of numbers. At a stretch, only one case study data has been possible to feed, and also, the input data collection will be sequential with respect to the number of processes in that case. For clarity, all the input data related to different cases (1,2,3) are shown in Figures 8, 9 and 10.

INPUT DATA

Lift Bracket -manufacturing												
Description		Unit of Measurement	Notations									
Number of machines in the line		in Nos		5								
Number of days all plants in the line are running		in no. of days		7	days continiously							
Category A	Losses category			Process-1 (Hydraulic shear cutting)		Process-2 (Drilling)		Process-3 (Gas cutting)		Process-4 (Welding -Co2 - GMAW)		Process-5 (Painting)
Planned stop	Availability & Management	in Minutes	PS	0		0		0		0		0
PI maintance		in Minutes	PMT	240		80		160		120		60
Tools changing		in Minutes	TCT	300		200		100		150		150
Failures		in Minutes	FA	0		0		0		0		0
Minor stoppages	performance	in Minutes	MS	0		0		25		30		15
Speed adjustment / line setting		in Minutes	SAT	0		0		15		10		0
Defect & rework	Quality	in Nos	D	0		150		75		150		175
Online inspection for complete sample	Line movement - performance	in minutes	OLI		30		30		30		30	
Material handling wastages/ reject / inspection		in nos	MH		50		150		50		75	
Category B												
Ideal cycle time	Output per piece	in Minutes	Cyt	2		3		0.5		4		1
Category C												
No. of goods stocked inbetween the processes	Inventory	in nos	I		500		500		100		100	

Figure 8: OMLE Assessment (current state) for five processes product line

INPUT DATA

Assembling - PRESSURE COOKER MANUFACTURING																
Description		Unit of Measurement	Notations													
Number of machines in the line		in Nos		7												
Number of days all plants in the line are running		In no. of days		7	days continiously											
Category A	Losses category			Process-1 (PLATE CUTTING)		Process-2 (COLD PRESSING)		Process-3 (WASHING/ POLISHING)		Process-4 (PUNCHING / PIERCING)		Process-5 (HANDLE ASSEMBLING)		Process-6 (SAFETY VALUE FIXING)		Process-7 (LABELING/ PACKING)
Planned stop	Availability & Management	in Minutes	PS	250		500		100		50		700		700		700
PI maintance		in Minutes	PMT	100		1200		60		250		60		60		60
Tools changing		in Minutes	TCT	1500		2500		60		300		60		300		50
Failures		in Minutes	FA	1000		1800		180		50		52		50		50
Minor stoppages	performance	in Minutes	MS	250		100		50		50		10		10		10
Speed adjustment / line setting		in Minutes	SAT	1000		1450		20		20		20		20		20
Defect & rework	Quality	in Nos	D	5		5		0		100		250		200		25
Online inspection for complete sample	Line movement - performance	in minutes	OLI		50		50		10		10		10		10	
Material handling wastages/ reject / inspection		in nos	MH		2		2		2		5		1		1	
Category B																
Ideal cycle time	Output per piece	in Minutes	Cyt	2		3		0.5		1		3		3		2
Category C																
No. of goods stocked inbetween the processes	Inventory	in nos	I		1500		1250		2500		10		10		10	

Figure 9: OMLE Assessment (current state) for five processes product line

INPUT DATA

Compressor Wheel Manufactruing																				
Description		Unit of Measurement	Notations																	
Number of machines in the line		in Nos		9																
Number of days all plants in the line are running		In no. of days		7	days continiously															
Category A	Losses category			Process-1 (Mold Making)		Process-2 (Baking)		Process-3 (AFP)		Process-4 (Knock Out)		Process-5 (Cutting)		Process-6 (Shot Blasting)		Process-7 (Initial Inspection)		Process-8 (Heat Treatment)		Process-9 (Final Inspection)
Planned stop	Availability & Management	in Minutes	PS	90		0		380		90		90		90		90		90		90
PI maintance		in Minutes	PMT	60		30		30		60		60		60		60		60		60
Tools changing		in Minutes	TCT	60		0		240		20		60		20		20		20		20
Failures		in Minutes	FA	60		60		240		20		40		20		20		20		20
Minor stoppages	performance	in Minutes	MS	100		0		300		20		40		20		20		20		20
Speed adjustment / line setting		in Minutes	SAT	60		0		100		60		60		20		200		200		200
Defect & rework	Quality	in Nos	D	200		60		480		10		20		24		160		12		100
Online inspection for complete sample	Line movement - performance	in minutes	OLI		40		20		10		12		5		25		25		20	
Material handling wastages/ reject / inspection		in nos	MH		20		100		12		5		2		2		2		1	
Category B																				
Ideal cycle time	Output per piece	in Minutes	Cyt	0.17		2		0.4		1		2		2		1		1		2
Category C																				
No. of goods stocked inbetween the processes	Inventory	in nos	I		600		20		600		100		50		750		750		600	

Figure 10: OMLE Assessment (current state) for five processes product line

By feeding the input data in the programmed software, the current status of effectiveness OMLE has been assessed. The effectiveness of the five-process product line under the current stage without any improvement is 74.79%, and the number of good pieces that come out from the product line is 2488 pieces with the line stock of 1200 pieces (as work in progress) in between the various processes of the five-process product line. Similarly, for the 7 and 9 process product lines, OMLE is 37.8% and 74.93%, respectively. The number of good pieces from the product line is 2391 pieces & 4948 pieces with the line stock of 5280 pieces & 3470 pieces (as work in progress) in between the various processes of the 7& 9 process product line respectively.

For the category-A and Category-B, the improvement (loss reduction, cycle time reduction) in the line has been sequentially carried out (iteration by iteration with changes in the reduction percentage with the slab of 10% & 5% from the minimum [efforts/time period /cost in kaizen] 10% to maximum [efforts/time period /cost in kaizen] of 90%) based on the feasibility for the type of product line.

For the category-C, the inventory (good pieces stocked –work in progress after the end of each process) has been sequentially varied (iteration by iteration with changes in percentage with the slab of 10% from the maximum [efforts/time period /cost in kaizen] of 90% reduction to a minimum [efforts/time period /cost in kaizen] of 30% improvement from current stock) based on the feasibility with respect to the type of product line.

For all the categories (A, B, C) of improvement, it has been executed with a maximum of four stages (stage-1-one process/parameter at a time to stage-4 – four process/parameter at a time). The results show the improvement in all categories (A, B, C) with a minimum of three options. Based on the engineer's working in the product line, can execute the necessary KAIZEN to address the bottleneck parameters. It has been adopted for all three case studies (five processes, seven processes, nine processes) taken for experimentation.

4.1. For case-1,2&3 (with inventory) combined level

By using the input data corresponding to the 5 process, 7 process and 9 process product line in the programmed software, improvement for the combined level of improvement (i.e., two categories (A&B, A&C, B&C) combination and three categories (A, B & C) combination have been evaluated (from the program).In the two categories combination say A & B - Category - A (best option from the single stage) with Category –B, A & C - Category - A (best option from singlestage) with Category –C, B&C - Category - B (best option from the single stage) with Category –C, the best option of category-A (from singe level) has considered as a current level and by addressing/attacking / changes in the cycle time of processes in the product line. The best options under these double and triple stages of categories presented in Tables 3, 4 and 5.

Table 3: OMLE improvement combined level for 5 processes product line with inventories

5 process, 7 days working - best options of Category A with B&C (combined level)								
		With change of inventory (from -90% to + 30%)						
		No. of process improvement	OMLE	Line output (Actual)	Possible Output (Theoretical)	Line Total Stock		Improvement - Loss details
	Current					in Nos.	% Of Variation	
	Category, Loss		74.79	2488	2895	1200		Nil
Double Stage	A&B	4	90.55	11067	11700	1200	0.00%	Process-1- Tool change loss reduced by 70%,Process-2- Tool change loss reduced by 70%, Process-4- Defect and rework loss reduced by 70%, Process-5- Defect and rework loss reduced by 70% +++++++++++++ Process-1- Cycle time reduced by 55%, Process-2- Cycle time reduced by 75%, Process-4- Cycle time reduced by 80%, Process-5- Cycle time reduced by 15%
	A&C	3	87.01	2894	2895	1400	16.67%	Process-1- Tool change loss reduced by 70%, Process-2- Tool change loss reduced by 70%, Process-4-Defect and rework loss reduced by 70%, Process-5- Defect and rework loss reduced by 70% +++++++++++++++ Process-1- 2- number of goods stocked increased by 30%, Process -3-4- number of goods stocked reduced by 30%, Process-4-5- number of goods stocked increased by 20%
	B&C	4	85.69	7712	8354	1510	25.83%	Process-1- Cycle time reduced by 35%,Process-2- Cycle time reduced by 60%, Process-4- Cycle time reduced by 70%, +++++++++++++++ Process-1- 2- number of goods stocked increased by 20%, Process2 - 3- number of goods stocked increased by 30%, Process-3 -4- number of goods stocked increased by 30%, Process-4-5- number of goods stocked increased by 30%
Trible Stage	A&B&C	4	91.89	11327	11750	1430	19.17%	Process-1- Tool change loss reduced by 70%, Process-2- Tool change loss reduced by 70%, Process-4-Defect and rework loss reduced by 70%, Process-5- Defect and rework loss reduced by 70%, +++++++++++++ Process-1- Cycle time reduced by 55%, Process-2- Cycle time reduced by 75%, Process-4- Cycle time reduced by 80%, Process-5- Cycle time reduced by 15% +++++++++++ Process-1-2- number of goods stocked increased by 10%, Process-23- number of goods stocked increased by 30%, Process-3-4- number of goods stocked increased by 30%, Process-4-5- number of goods stocked increased by 30%

In the combined level of improvement for the 5-process product line, the best OMLE obtained in the 3-category combination is about 91.89%. The good output from the line is 11327 pieces. It has obtained by adopting changes in the categories in A (4 parameters changes), B (4 parameters changes), and C (4 parameters changes) as given in the last row (A&B&C) in the table-10. In the combined level of improvement for the 7-process product line, the best OMLE obtained in the 2-category combination is about 77.06%. The good output from the line is 6540 pieces. It has been obtained by adopting changes in the categories in A (3 parameters changes), B (4 parameters changes) as given in the first row (A&B) in the Table 4.

Table 4: OMLE improvement combined level for 7 processes product line with inventories

7 process, 7 days working - best options of Category A with B&C (combined level)								
		With change of inventory (from -90% to + 30%)						
		No. of process improvement	OMLE	Line output (Actual)	Possible Output (Theoretical)	Line Total Stock		Improvement - Loss details
	Currer					in Nos.	% Of Variation	
	Catego Loss		37.8	2391	4610	5280		NIL
	A&B	4	77.06	6540	6540	5280	0.00%	Process-1- Tool change loss reduced by 70%, Process-2- Tool change loss reduced by 70%, Process-2- Failure loss Reduced by 70% ++++++++++++++++ Process-2- Cycle time reduced by 35%, Process-5-6- Cycle time reduced by 50%, Process-6- Cycle time reduced by 50%, Process-7- Cycle time reduced by 65%
Double Stage	A&C	4	64.6	4175	4660	6486	22.84%	Process-1- Tool change loss reduced by 70%, Process-2- Tool change loss reduced by 70%, Process-2- Failure loss Reduced by 70% +++++++++++++++ Process- 1-2- number of goods stocked increased by 30%, Process3-4- number of goods stocked increased by 30%, Process- 5-6- number of goods stocked increased by 30%, Process- 6 -7- number of goods stocked increased by 30%
	B&C	4	71.98	4652	4660	6486	22.84%	Process-5- Cycle time Reduced by 40%, Process-6- Cycle time Reduced by 35% ++++++++++++++++++++++ Process-1-2- number of goods stocked increased by 30%, Process3-4- number of goods stocked increased by 30%, Process-5-6- number of goods stocked increased by 30%, Process-6-7- number of goods stocked increased by 30%

In the combined level of improvement for the 9-process product line, the best OMLE obtained in the 3-category combination about 93.07%, good output from the line is 9845 pieces. It has been obtained by adopting changes in the categories in A (4 parameters changes), B (3 parameters changes) and C (4 parameters changes) as given in the last row (A&B&C) in table5. The summarized information about the OMLE improvement among the single level and combined level for the 5, 7 and 9 process product lines shown in table 6.

By referring to the summarized results table, for all the 5, 7 and 9 processes product line, the triple level will be better than double level and also double level will be better than a single stage of categories (A, B, C) associated losses/parameter reduction. Compared with the above two, the improvement (OMLE) achieved in a single stage will be better than combined stages, i.e., with minimum change of losses will significantly impact effectiveness. The computation time for 3 to 25 processes in the product line has been numerically tested, and the program running time towards execution of results varies from 3 minutes to 15 minutes in the Intel Pentium core processor. The program consists of 2500 lines with 28 conditions.

5. Programming Results validation

To understand the effectiveness summarized of the developed optimization program in identifying the bottleneck processes and categories (A, B, and C) with the corresponding parameter/losses towards executing improvement validation have performed in a real case study organization. The

Table 5: OMLE improvement combined level for 9 processes product line with inventories

9 process, 7 days working - best options of Category A with B&C (combined level)								
	With change of inventory (from -90% to + 30%)							
		No. of process improvement	OMLE	Line output (Actual)	Possible Output (Theoretical)	Line Total Stock		Improvement - Loss details
	Current					in Nos.	% Of Variation	
	Category, Loss		74.79	2488	2895	1200		Nil
	A&B	4	93.07	9845	9845	3470	0.00%	Process-9- Speed adjustment/ Line setting loss reduced by 40%, Process-3- Defect and Rework loss reduced by 50%, Process-3- Minor stoppages loss reduced by 70% +++++++++++++++++++ Process-2- Cycle time reduced by 70%, Process-5- Cycle time reduced by 50%, Process-6- Cycle time reduced by 55%, Process-9- Cycle time reduced by 45%
Double Stage	A&C	2	87.05	5790	5790	3417	-1.53%	Process-9- Speed setting/ Line setting loss reduced by 40%, Process-3- Defect and Rework loss reduced by 50%, Process-3- Minor stoppages loss reduced by 70% ++++++++++++++++++++ Process-1-2- number of goods stocked reduced by 10% , Process-2-3 - number of goods stocked increased by 30%
	B&C	2	93.07	9845	9845	3470	0.00%	Process-2- Cycle time reduced by 60%, Process-5- Cycle time reduced by 50%, Process-6- Cycle time reduced by 50%, Process-9- Cycle time reduced by 45% +++++++++++++ Process-2-3 number of goods stocked reduced by -20%, Process-5-6 -number of goods stocked increased by 10%
Trible Stage	A, B&C	3	93.07	9845	9845	3080	-11.24%	Process-9- Speed adjustment/ Line setting loss reduced by 40% Process-3- Defect and Rework loss reduced by 50% Process-3- Minor stoppages loss reduced by 70% +++++++++++++++++++ Process-2- Cycle time reduced by 70%, Process-5- Cycle time reduced by 50%, Process-6- Cycle time reduced by 55%, Process-9- Cycle time reduced by 45% +++++++++++++ Process-1-2- number of goods stocked reduced by 80%, Process-5-6 - number of goods stocked increased by 30%, Process-6-7- number of goods stocked increased by 10%

Table 6: Summary of Best OMLE improvements for various processes with inventory

			5 Processes	7 Processes	9 Processes
	Current	OMLE	74.79	37.8	74.93
		Good pieces line output	2488	2391	4984
Improve ment by addressing the bottlenec k paramete r/process, losses	Single level category improvement	OMLE	84.27 Category - A	62.21 Category-B	93.06 Category - B
	Double level category improvement	Good pieces line output	11067	6540	9845
	Triple level category improvement	OMLE	91.89 Category– A, B&C	NIL	93.07 Ctegory– A,B&C
		Good pieces line output	11327		9845

Table 7: Summary of Best OMLE improvements for various processes with NIL inventories

			5 Processes	7 Processes	9 Processes
	Current	OMLE	58.7	0	34.72
		Good pieces line output	1750	0	2063
Improve ment by addressing the bottlenec k paramete r/process, losses	Single level category improvement	OMLE	72.11 Category - A	6.42 Category-A	69.17 Category - B
		Good pieces line output	2065	524	7473
	Double level category improvement	OMLE	77.53 Category – A&B	16.61 Category – A&B	
		Good pieces line output	9867	2034	NIL
	Triple level category improvement	OMLE			
		Good pieces line output	NIL	NIL	NIL

validation of the effectiveness evaluation program has carried out in the 7-process pressure cooker (domestic / household purpose) manufacturing organization. The complete flow chart of the sequence of operation is in figure-11.

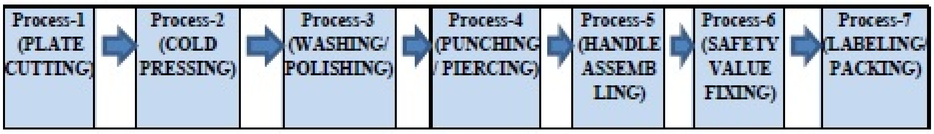


Figure 11: 7-process pressure cooker manufacturing process chart

The conventional pressure cooker is manufactured as per the flow chart above (Figure-11). It starts with Circle cutting from the sheet in hydraulic punching press as per pan and lid dimensions, and then by pressing the cut plate, the required shape has been formed. Attach the handle in the body to two sides for easy handling. Similarly, attach a handle for the lid with two sides. The attachment has been made with fasteners.

Similarly, the safety value and gasket have been attached to the lid portion. These are then stamped, polished, or anodized, and the samples are drawn for final product pressure testing. These products have to adhere to IS 2347 and relevant quality and material specifications. The company has continuous customer orders (same variety /model) for 6 months on a weekly basis. In this 7-process manufacturing, the raw material (aluminium plate) has been purchased from the same supplier (Hindalco) at one stretch towards meeting the six months requirement (one lakh pieces) of the customer. So, there are no changes in the sequence of operation, equipment modification/alteration. Moreover, the contributing variables towards meeting the customer requirement are the operating environment and the operator's very minimum in the high autonomation organization. So this case study (7 process – pressure cooker manufacturing) has been considered for validation compare with the case of 5 process and 9 process product lines.
The output obtains from the programming (program) and after execution of kaizen on the bottleneck process, losses suggested by the program are tabulated in table 8.

The customer requirement has been categorized every week (weekly requirement is 4166 pieces) and follows up the adherence. As of now, the manufacturing organization is possible to make 2390 pieces per week and for the 24 weeks, it is possible to deliver from the current manufacturing site-1 (Coimbatore, South India) is 57360 pieces only remaining pieces has been planned to deliver from another manufacturing site-2 (Hosur, South India) in last 8 weeks. Because in another manufacturing site-2 (Hosur) from week-1 to week-16 is fully committed towards export business. At the current stage in the manufacturing site-1, the customer schedule adherence is only 57.36%. So, the management is interested in adopting kaizen on the bottleneck process without disturbing the existing customer-approved manufacturing sequence, process variables. Also, the organization is not interested in varying the inventory between the processes. So the category –C has not been taken into account for effectiveness improvement. As per the program execution, the bottleneck parameter/losses and the corresponding processes in the product line for best OMLE are identified and fixed as a target towards kaizen implementation in the actual product manufacturing line sequentially. From the program, the improvement obtains from Category –A is more compared with other individual category and their combination. Furthermore, it is an old traditional plant with young, energetic employees, so it has been planned to execute kaizen on category -A related losses (stage by stage) every week. Even though the best option related to category –A suggesting towards reduction of Tool change loss in process-1&2 - by 70%, and failure loss in process-2 by 70%, it is practically

Table 8: Simulated results validation with a real case study

Simulated results				*Actual*				
OMLE (estimated)	***Number of good pieces out from the product line (estimated from the program)***	***Category reduction***	***Areas of improvement***	***Week***	***OMLE***	***Number of good pieces out from the product line (actual)***	***Customer schedule adherence (Delivery quantity / Ordered quantity)***	***Remarks***
37.8	*2391*			*1*	*37.80*	*2390*	*57.36%*	*Current stage*
59.19	*3744*	*A (BEST option)*	*process-1 Tool change loss reduced by 70%, process-2- Tool change loss reduced by 70%, process-2- Failure loss by 70%*	*2*	*46.34*	*2900*	*69.61%*	*Implementation of kaizen towards reduction of loss in process-2 result with tool change loss time has been reduced from 2500 minutes to 875 minutes (65%) from category –A*
				3	*51.08*	*3230*	*77.53%*	*Because of effective implementation of jishukozen (CLIR) towards reduction of loss in process-2 result with failure (breakdown), loss time has been reduced from 1800 minutes to 900 minutes (50%) from category –A*
				4	*56.6*	*3580*	*85.93%*	*Implementation of kaizen towards reduction of loss in process-1 result with tool change loss time has been reduced from 1500 minutes to 450 minutes (70%) from category –A*
77.05	*6539*	*A&B (BEST option)*	*Process -2- cycle time reduced by 35% Process-5 cycle time reduced by 50% Process-6- cycle time reduced by 50% Process-7- cycle time reduced by 65%*	*5*	*58.62*	*3700*	*88.81%*	*Implementation of kaizen towards reduction of loss in process-5 result with cycle time per piece has been reduced from 3 minutes to 2.4 minutes (20%) from category –B*
				6	*71.35*	*4500*	*108%*	*Implementation of kaizen towards reduction of loss in process-6 result with cycle time per piece has been reduced from 3 minutes to 2.49 minutes (17%) from category –B*

not feasible with the existing process operating condition. From week 2 to week 4 these losses in the process-1 and process-2 are planned to reduce by adopting different approaches (kaizen) and reached with process-2 tool change loss with a reduction of 65% (compare with the target of 70%), process-2 failure loss with reduction of 50% (compare with the target of 70%) and process-1 tool change loss with reduction of 70% (compare with the target of 70%), result with OMLE of 56.62% and weekly good output quantity reached to the customer is 3580 pieces (35% improvement). It is tough to improve the OMLE based on Category-B (cycle time) in the old traditional and established process, so it has been planned to address the assembly operation (i.e., in process-5, process-6, and process-7) only. From the program (by feeding the week 4 process time as input data after implementing kaizen related to category A), the improvement obtains for the category –A with B is more compared with other combinations of categories. The best option related to category –A with B suggesting towards reduction of cycle time in process -2 by 35%, reduction of cycle time in process -5 by 50%, reduction of cycle time in process -6 by 50%, and reduction of cycle time in process -7 by 65%. As mentioned earlier, only process-5, 6, 7 are considered task force projects and executed fully. In the sixth week, with the adoption of kaizen and change in packing, printing procedure (with the approval of customer), the cycle time in process -5 reduced from 3 minutes to 2.4 minutes and also reduce the cycle time in process-6 from 3 minutes to 2.49 minutes result with OMLE of 71.35% and delivery quantity per week is 4500 pieces against the TACOQ (Target Achievable Customer Order Quantity) of 4166 pieces per week. From this, it is clear that the customer order has been possible to meet with in the specified time in the manufacturing site-1 itself. In week 24 the number of pieces required to meet the customer demand is 3200 pieces only. So, from this validation report, it has been clear that the OMLE evaluation and optimization programming system will identify the actual bottleneck parameter, losses, and process in the n process product line.

6. Conclusion

Many managers have failed to understand the real bottleneck process, and because of their initial excitement and eagerness to get started with cycle time reduction will lead to not able to reach the results in the allocated time slot and also because of more number of processes in the product line the calculation becomes cumbersome. The designed package will address all these issues and valuable for the manager to take the right direction and achieve the target at the right time. Globalization leads industries towards adopting OMLE as the best performance index towards estimating the CLMS and acting as a benchmark index towards reaching world class status. Rightly identify the bottleneck parameter and the corresponding process in the product line lead to success in a short span of time. The success of the OMLE evaluation program and its improvement require active and robust support from all organization levels in the organization. The case study results show that improvements that happened in the three categories (A, B, C) will have an effect on the good output from the product line.

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