THE USE OF DMAIC SIX-SIGMA FOR PRODUCTIVITY 'GAP' REDUCTION IN MANUFACTURING PRODUCTION LINE

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Abstract

DMAIC methodology is fundamentally viewed as a process that focuses on improvement and variation reduction through the use of DMAIC improvement projects. With globalization and the fourth industrial revolution, organizations are obliged to put in place mechanisms that champion process efficiency. This study used the DMAIC concept into productivity 'gap' reduction between planned shift work Time on the steel manufacturing production line and the actual shift work Time on the line in a manufacturing Industry. After the 'gap' activities is recorded, the 'gap' analysis is conducted using causes and effect diagram and Pareto charts. And the outcome has revealed areas that have contributed to the Line Manager (LM) daily routine inefficiency, among which include 'meetings', 'scanning', 'follow-up', 'walking' and others. Proposed improvement is listed for both the "***out of Line Manager' control***" 'gap' activities and the" ***within Line Manager' control***" 'gap' activities. The study recommends the restructuring of work tasks and systems in order to optimize LM's productivity and improve motivation.

Keywords: DMAIC Six-Sigma, Pareto Chart, Causes and Effect Diagram, Manufacturing Production Line,

Introduction

The current Covid-19 pandemic has added to the already turbulent economic condition facing the world at large and the manufacturing sector in particular. Also, with the growing competitiveness and customers demand for high quality products, companies are obliged to promote efficiency, reduce production cost and enhance productivity (Mohamad et al., 2019). Among available strategies to be used for that end include the application of Six-sigma. Six-Sigma is a highly disciplined process that enables world-class quality and continuous improvement methods to achieve the highest level of customer satisfaction (Ohno, 1988).
According to Mohamad et al., (2019), Six Sigma efforts are directed towards the minimization of waste and non-value-added activities (NVA) while maximizing customer satisfaction. The implementation of a Six-Sigma methodology aims at achieving error-free business performances, focusing on improving quality by helping organizations produce products and services better, faster and cheaper (Anup and Shende, 2011). The Six Sigma has the potential to realize cost savings and improved quality on the shop floor (Kumar and Sosnoki, 2009).
The word associated to six-sigma such as 'waste' come from the Japanese word 'Muda' referring to the human activities that exploit the resources in the company but does not create any profit or value (Mohamad et al., 2019). Taiichi Ohno (1988), a former Toyota executive, presented this concept of 'Muda' in the manufacturing industry. In Table 1 below, seven classes of waste that typically affect a manufacturing process was defined by Ohno (1988):

Table 1: Seven Waste of Lean Manufacturing

Types of waste	Explanations
Over processing	Adding more value to a product than the customer actually requires such as painting area that will never be seen or be exposed to corrosion.
Waiting	It is the act of doing nothing or working slowly whilst waiting for a previous step in the process. Waiting occurs when operators stand in between two operations for reason such as late delivery of essential products to replenish the current shortage.
Transportation	It is the movement of products from one location to another. E.g.: This could be from a WIP warehouse to the welding shop or from the production facility in china to the assembly line in America. This transportation adds no value to

	the product.
Inventory	Are the raw materials, work in progress (WIP) and finished goods stock that is held, we often hold far more than is required to produce goods and services when the customer wants them using Just in Time (JIT).
Motion	Waste being a process step that is not value adding, moving is not necessarily working. The main causes of the waste of motion are with regards to cell layout, placing product at floor level on pallets, poorly arranged space, tools that are disorganized, lack of space and organization for component parts and so on.
Defect	Defects are when products or service deviate from what customer requires or the specification. Defect can be caused by many factors; among which includes the product design, non-standard operation, different in the way that processes are undertaken by different operator on different shift.
Overproduction	Overproduction is making products in too great a quantity or before it is actually needed leading to excessive inventory.

In order to achieve Six-Sigma level quality, in relation to this study objective, Six-Sigma provides an improvement framework known as Define-Measure-Analyze-Improve-Control (DMAIC). DMAIC is a very structured approach with a very detail analysis process of implementing the improvement (Mohamad et al., 2019). DMAIC helps solve business problems by providing a road map for solutions from the start of the manufacturing process till finish while producing bottom line results.
SIX-Sigma, according to Antony et al. (2005), is not known by many Small-and Medium sized manufacturing companies, nor have resources to implement it. Following poor appraisal, two days' time study was conducted to the Line Manager "XY" (LM) at a steel manufacturing in Kwazulu-Natal, South Africa. The study findings revealed a "gap" between the time planned (in minutes) for the LM to execute activities during a shift and the actual time (in minutes) taken to complete the planned activities. The "gap" represents all range of wastes included among Taiichi Ohno (1988) Seven Waste of Lean Manufacturing list. To reduce the productivity 'gap', the study used the following five steps' DMAIC Six-Sigma objectives:

- Definition of the Line Manager's daily and individual activities.
- Measurement of the Line Manager's daily and individual activities.
- Analysis of each of the Line Manager's daily and particular activities, performances.
- Based on the outcome of the analysis, highlighting potential areas influencing 'gap' reduction and of productivity improvement.
- Proposing mechanism for sustaining the improvement.

DMAIC Methodology

SIX-Sigma DMAIC

DMAIC is a "simple performance improvement model" of an existing process to help firms achieve significant performance improvement by reducing the cost (Pyzdek and Keller, 2014). According to Galli and Kaviani (2017), Six Sigma identifies causes of variation to develop improvement strategies. The selected Six-Sigma improvement framework used is DMAIC. DMAIC problem solving strategy relies on the following five phases: Define Measure, Analyse, Improve and Control. Pyzdek (2013) described these phases as follows:

- **Define** phase – covers customer requirement, critical to customer (ctc), process mapping and flowcharting, project charter development, problem solving tools, and the so-called 7 Managements tools (Affinity Diagrams, Tree Diagrams, Interrelationship diagraph, Process Decision Program charts (PDPC), Matrix diagrams, Prioritization matrices, Activity Network diagram).
- **Measure** phase - covers the principles of measurement, continuous and discrete data, scales of measurement, an overview of the principles of variation, and repeatability-and-reproducibility (RR) studies for continuous and discrete data.
- **Analyse** phase - covers establishing a process baseline, how to determine process improvement goals, knowledge discovery, including descriptive and exploratory data analysis and data mining tools, the basic principles of statistical process control (SPC), specialized control charts, process capability analysis, correlation and regression analysis, analysis of categorical data, and non-parametric statistical methods.
- **Improve** phase - covers project management, risk assessment, process simulation, design of experiments (DOE), robust design concepts (including Taguchi principles), and process optimization.

- **Control phase -** covers process control planning, using SPC for operational control and pre-control.

Figure 1 shows the DMAIC Six Sigma process flow chart.

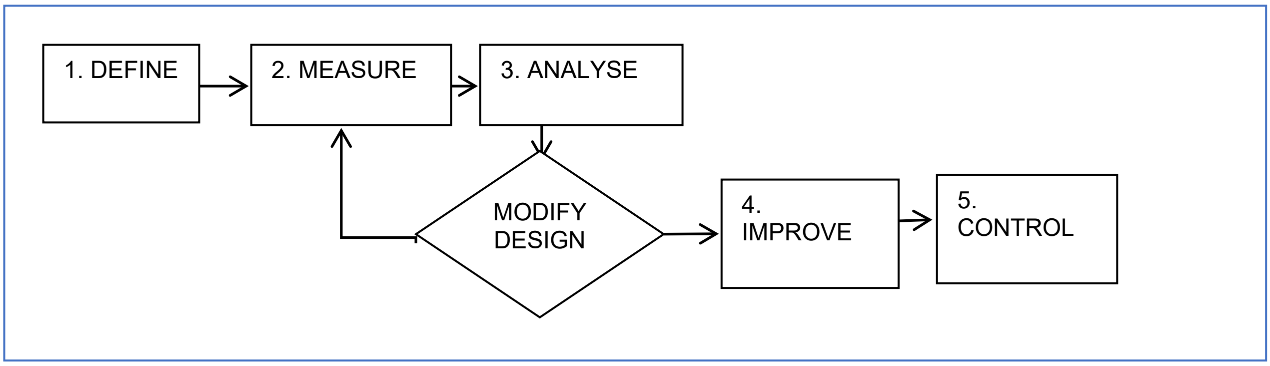

Figure 1: DMAIC process flow chart

DMAIC methodology guides the project team from the project definition (Define) to maintaining the results (Control) (Zugelder, 2012). According Jones (2014), Six Sigma (SS) main ideas and mindset is based on taking a business problem and converting it into an engineering problem that uses statistics, then develop an engineering solution, and finally converts that to a business solution. SS mindset is explained in Figure 2 as followed.

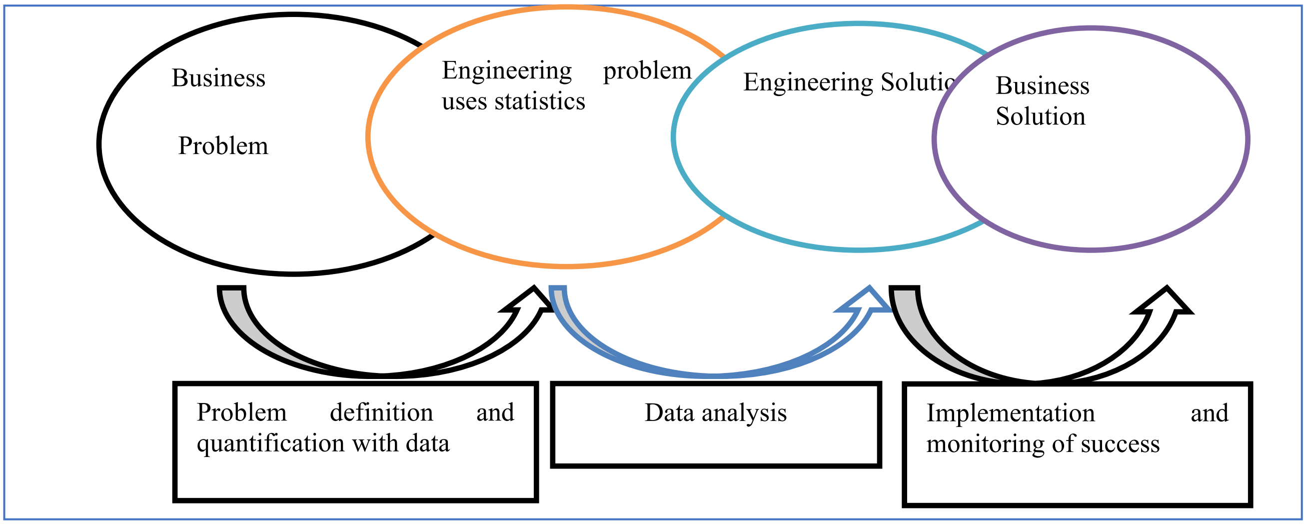

Figure 2: Role of industrial systems engineering thinking and methods (Zugelder, 2012).

DMAIC Implementation

Figure 3 below shows the roadmap performance of DMAIC methodology.

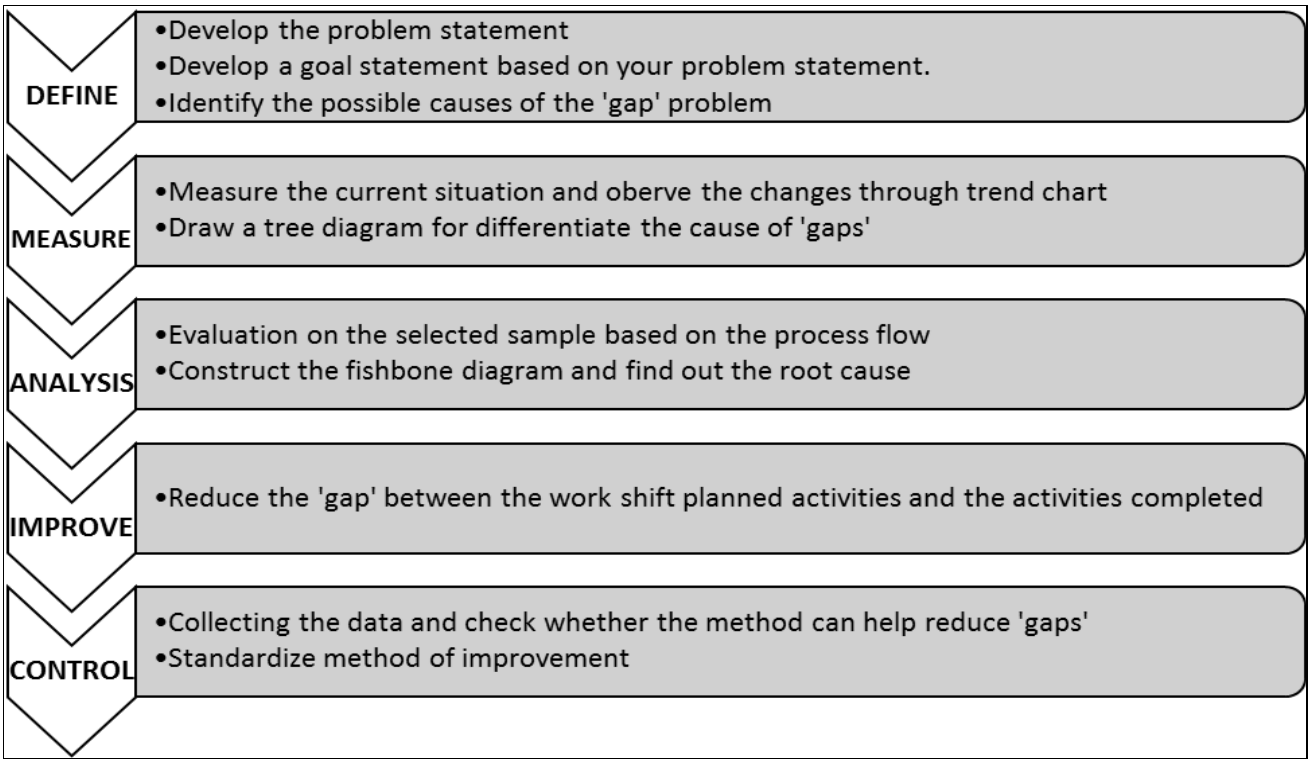

Figure 3. Process roadmap of DMAIC

As indicated in the study aim and objectives, in order to reduce the “gap” between planned activities per shift and the completed activities by the studied Line Manager (LM) in the aftermath of the two days’ work study, six-sigma DMAIC steps were implemented to expose all range of wastes associated LM daily activities.

Define

The first step for the six sigma DMAIC process consists of defining the problem statement. After a poor appraisal, two days’ Work Study was conducted on the daily activities of a Line Manager “XY”. The study defines the Line Manager’s “XY” production li3ne’ tasks as well as the duration taken to perform those tasks as shown in Table 2. The daily activities (task) listed in table 2 were converted into percentage.

Measurement

Time study was used to measure the Line Manager “XY” daily activities and identify the reason for the poor appraisal. After weeks of observations, daily activities of Line Managers were listed down and compared to past study conducted on the similar lines. Using previous study conducted Managers as benchmark, a stop watch was used to identify the duration it takes to complete the Line Manager “XY” tasks and activities. The findings for both the time (in minute) and the activities from L.M “XY” study were recorded in Table 2 below. Table 2 also details a benchmark for all the manufacturing Line Managers’ daily activities and duration each activity takes to fulfill the given tasks and the percentage. Table 2 below lists all ‘planned’ and ‘actual’ activities (relevant or irrelevant) from Task 1 (Production Control), Task 2 (Manufacturing excellence), Task 3 (Admin), Task 4 (Requisitions), Task 5 (Tea/Lunch) and Task 6 (Idle Time). The ‘planned’ LM “XY” daily activities included the ‘Time’ and the ‘percentage’ representation in comparison the “100%” total of all the 6 tasks. While the ‘actual’ time study results show the outcome of the two days study.

Table 2. Planned Line Manager’ Daily activities vs. Actual Line Manager’ Daily activities

PLANNED			**ACTUAL**			
Task	**Time (min)**	**Percentage (%)**	**Time (min)**	**Percentage (%)**	**Time (min)**	**Percentage (%)**
	Line Managers Benchmark		**Line Manager “XY” (Day 1)**		**Line Manager “XY” (Day 2)**	
Task 1: Production control	**230**	**48%**	**99**	**21%**	**63**	**13%**
Quality	60		39		28	

Verify standards	35		0		0	
Discipline	30		0		0	
Control line feeder	30		0		3	
Discipline Procedures	15		0		0	
Control staff	45		0		0	
Planning	15		60		32	
Task 2: Manufacturing excellence	**115**	**24%**	**76**	**16%**	**59**	**12%**
Check and calculate score sheets hourly	40		36		29	
Daily score sheet reconciliation	30		0		0	
Feedback performance to prod manager	15		40		30	
Update ME board	30		0		0	
Task 3: Admin	**60**	**13%**	**119**	**25%**	**209**	**44%**
Return to work interviews & Submit forms	15		34		45	9.4%
Time sheets & overtime	15		29		61	12.7%
Shift pattern	10		30		38	7.9%
Make job cards and follow up	10		5		27	5.6%
Make GRN	10		20		38	7.8%
Task 4: Requisitions	**30**	**6%**	**0**	**0%**	**0**	**0%**
PPE requisitions	15		0		0	
Material requisitions	15		0		0	
Task 5: Tea / lunch	**45**	**9%**	**45**	**9%**	**45**	**9%**
Task 6: Idle Time	**0**	**0%**	**45**	**9%**	**45**	**9%**
Total	**480**	**100%**	**480**	**100%**	**480**	**100%**

The benchmark in Table 2 for Planned Line Manager "XY" Daily activities) reveals that in a 8 hours shift, the Line Manager (LM) should spend a tally of 230 minutes or 48% of the total tasks in the 'production control'. Among the activities directed by the LM during the first Task include among many, quality controls, verify standard, discipline, control line feeder and control staff. The Time it tasks to accomplish each activity in association with Task 2 were also listed. Other tasks including 'manufacturing excellence' with 115 minutes (24%), 'Admin' works with 60 minutes (13%), 'requisitions' with 30 minutes (6 %), finally 45 minutes for breaks per shift (9%). As for the 'Actual' activities, the two days actual daily tasks and activities completed listed in Table 2 for work completed by Line Manager "XY" revealed 'gaps' in term of 1) the activities conducted, 2) the time it takes to conduct those activities, and 3) the overall percentage of activities per task.
Figure 4 below shows for instance that among the planned activities listed during the 'production control' task, only two activities (Quality control and production Planning) were conducted by the LM "XY" during both days. Highlighting the number of active activities in comparison to one originally planned assisted expose the Line Manager "XY" inefficiencies. 'Production control' for instance recorded 0 minutes in 5 critical activities (verification of standard, discipline, control line feeder, discipline procedures and control staff) conducted during that task. To be noted that the 'discipline' activity represents a management approach used to modify undesirable performance in manufacturing process or production line.

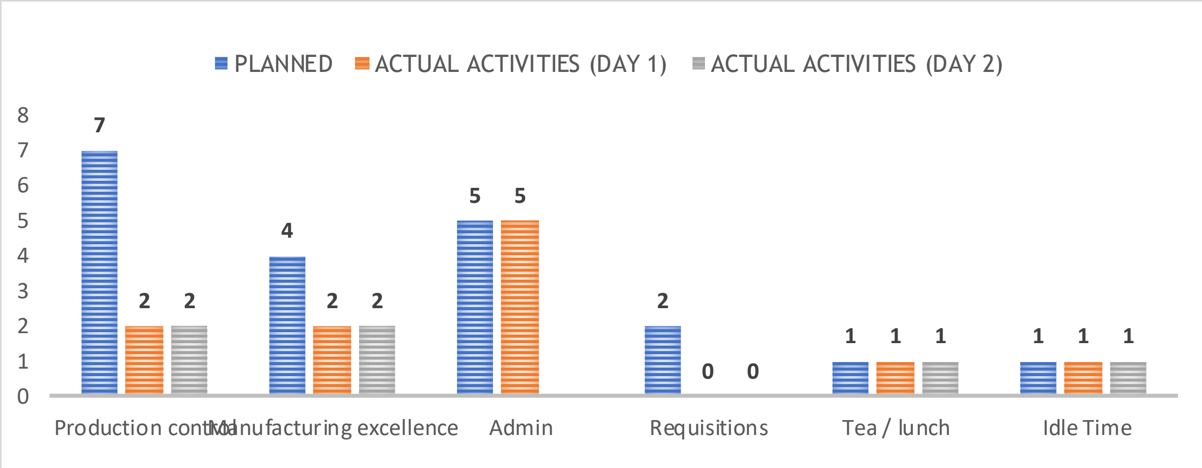

Figure 4: Number of planned vs. Actual activities

Figure 5 below shows the percentage of activities (planned and completed) per task by the Line Manager "XY". The results have revealed that in most of the activities, the LM "XY" was unable to reach the benchmark except during "Tea/Lunch". For instance, there was no 'idle time' during the benchmark operation. Unfortunately, the Line manager "XY" two days studies has seen an increase of 29% (day 1) of idleness and 22% (day 2). Such sharp increases need investigation for its reasons to be clarified and corrected for productivity gains. Similarly, the drastic increase in 'admin' time on the second day of LM "XY" studies.

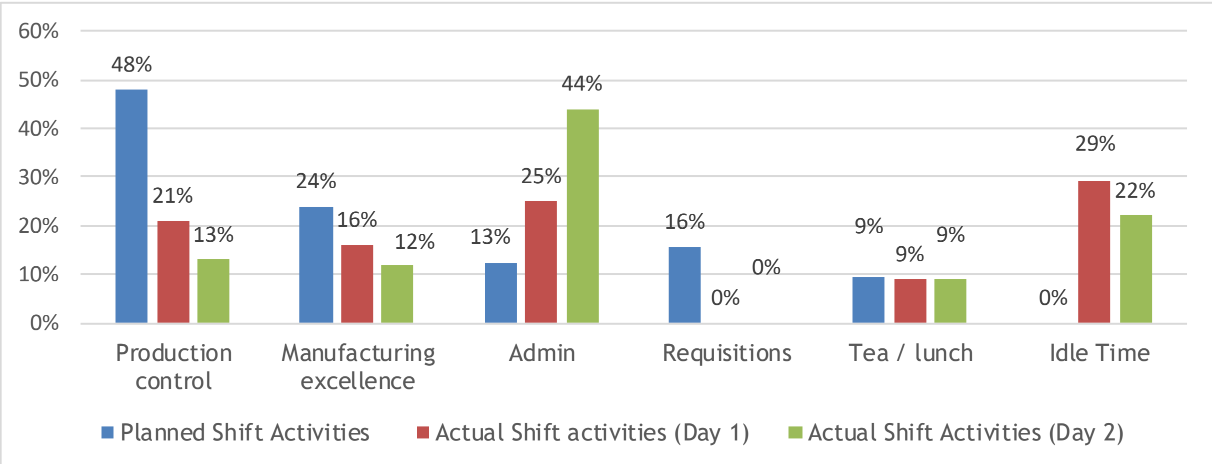

Figure 5: Planned vs. Actual (Day1,2) Shift Activities

Analysis

The outcome in Figure 4 and in Figure 5 has revealed a "gap" between planned activities and activities completed (actual) by the Line Manager "XY". For instance, on the 'production control' in the task 1, out of the 48% of planned activities, only 21% were completed by Line Manager "XY" on DAY 1 while 13% on DAY 2. Furthermore, both DAY 1 and DAY 2 in Figure 5 have shown the 'gap' existing between the planned and actual activities. And, these 'gaps' were graphically illustrated in Figure 6. For instance, a large "gap" of 27% was shown between the planned 'production control' daily activities and the actual activities in DAY 1, meanwhile a 'gap' of 35% was shown for DAY 2. As for the "admin", unlike the previous two tasks showing a decrease in time and percentage, the 'admin' task has shown an increase was shown by 13 % in DAY 1, and by 32% in DAY 2. Looking into the activities planned and completed in relation to 'admin' in Table 2, activities such as 1) spending more time filling, 2) returning to work interviews, 3) filling Time sheets or 4) overtime and others were the reason for the increase.

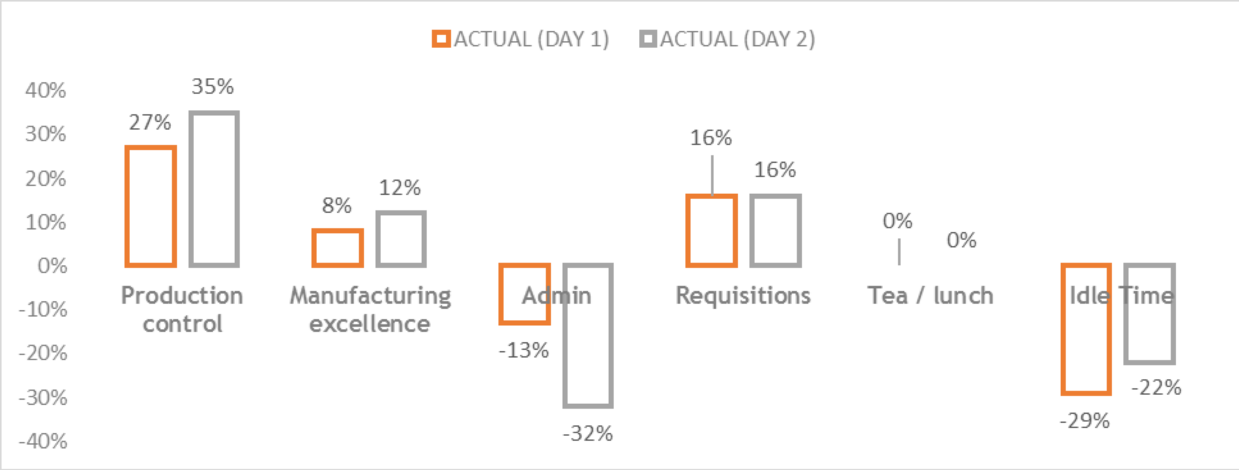

Figure 6: Different between Planned vs. Actual (Day1,2) Shift Tasks

Figure 7 evaluates the overall 'gap' difference between 'planned' tasks and activities and the 'actual' tasks and activities during the 2 days study. A 49% 'gap' was revealed between the tasks 'planned' and the one 'completed' by the Line Manager "XY".

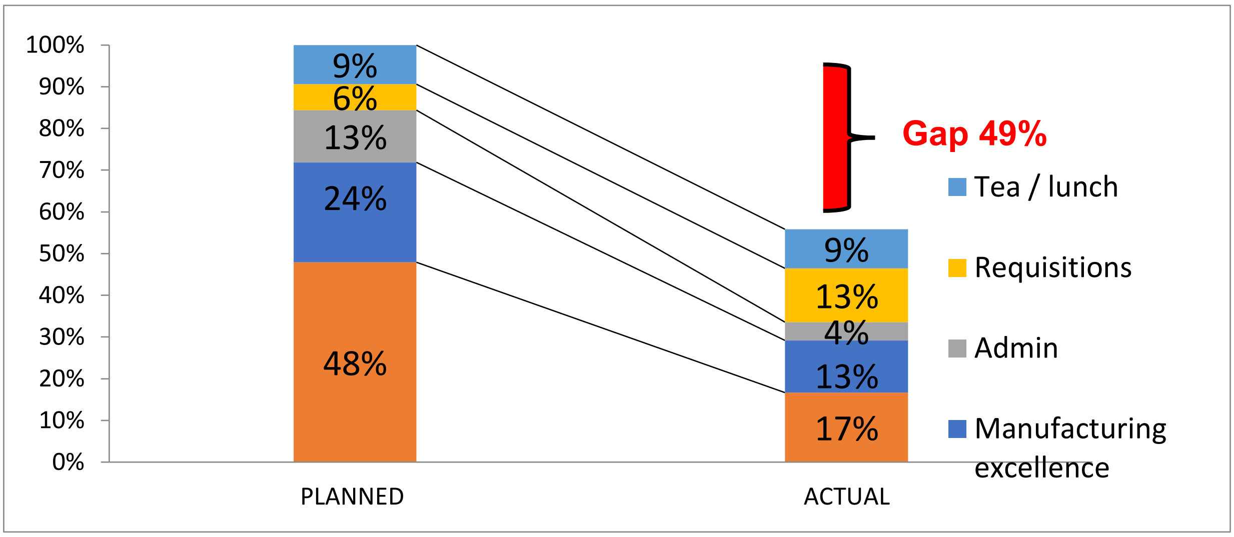

Figure 7: Planned vs. Actual (Average of 2 days) daily Shift Tasks

Furthermore, Table 3 analyzes the 49% 'gap' highlighted in Figure 7 for activities requiring improvements. For an effective improvement process, activities from the LM "XY" were categorize between the one that are '***out of line managers' control***' and the one that are '***within line manager' control***' activities in Figure 8. '***Out of line managers' control***' activities are one that occurs out of the original planning or production line benchmarking. While '***within line manager' control***' activities are one that occurs within the original planned operations. With a gross salary of R25, 000, 6 days per week and 8 hours shift, Line Manager "XY" makes on average R 2.17 per minute. Table 3 below shows the Planned vs. Actual daily activities 'gap' for line managers' highlighting the duration (min), the 'gap' percentage per task, as well as the amount in South Africa Rand the line manager "XY" waste daily by operating unplanned activities.

Table 3: Planned vs. Actual daily activities 'gap' for line managers'

GAP			
Activities	**Duration (Min)**	**Percentage**	**Waste (R)**
MEETINGS	**83**	**17%**	**R 180.11**

Y/z manager meeting	67		R 145.39
Meeting with the team	16		R 34.72
Planning meeting	0		R 0
Other meetings	0		R 0
WALK	**3**	**1%**	**R 6.51**
Fetch parts	3		R 6.51
Check stock from suppliers	0		R 0
Walk to other plans	0		R 0
SCANNING	**62**	**13%**	**R 134.54**
Scan swap cards	62		R 134.54
FOLLOW-UP	**35**	**8%**	**R 75.95**
Requisitions	10		R 21.7
Job cards	8		R 17.36
Tool maintenance progress	9		R 19.53
Follow up on raw material	8		R 17.36
OTHER	**50**	**10%**	**R 108.50**
Feed the line	15		R 32.55
Drive forklift	15		R 32.55
Extended breaks	20		R 43.40
Total	**233**	**49%**	**R 505.61**

Table 3 findings reveals that the line manager “XY” daily ‘meetings’ were the most time-wasting activity with a total of 83 minutes while costing the company a total of R 180.11 daily. ‘Scanning’ was the second biggest waste with “XY” taking 62 minutes to scan while wasting another R134.55 of the company time and money.
In total, Table 3 has shown that the manufacturing company is wasting R 505.61 per day on average on the salary destined to LM “XY”, representing 48.53% (R12, 134.64) worth of “XY” monthly salary.
With Table 3 findings, a Pareto Chart was developed in Figure 8 with the aim of highlighting “***out of line managers' control***” and “***within Line Managers' control***” ‘gap’.

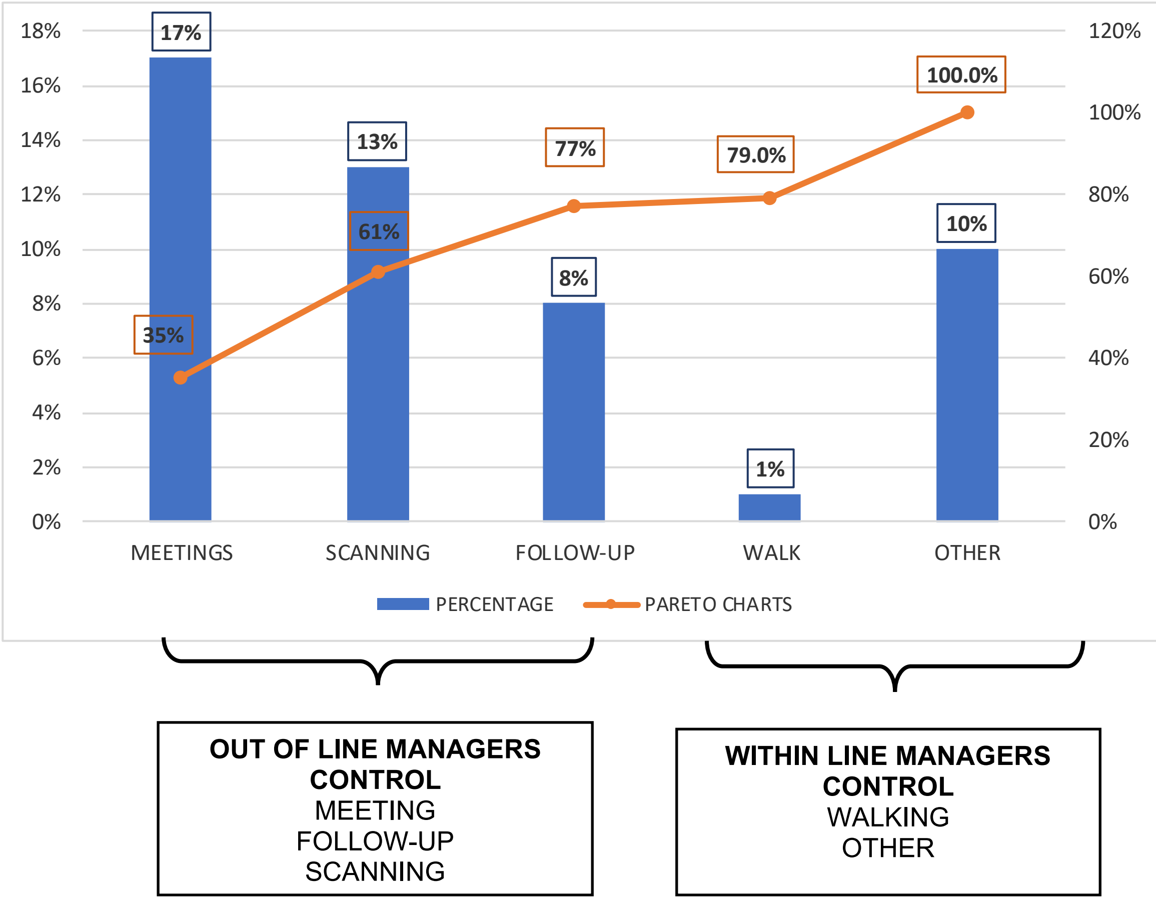

Figure 8: Pareto chart of 49% GAP for daily Shift Activities

Figure 8 patterns revealed that "***out of line managers' control***" included meetings, scanning and follow-up. Meanwhile, the "***within line managers' control***" included walking, looking for resources and other (Drive Forklift, Extended breaks, feed the line). Following the Pareto Chart, Figure 9 below illustrates those 'gap' activities in a cause and effect diagram.

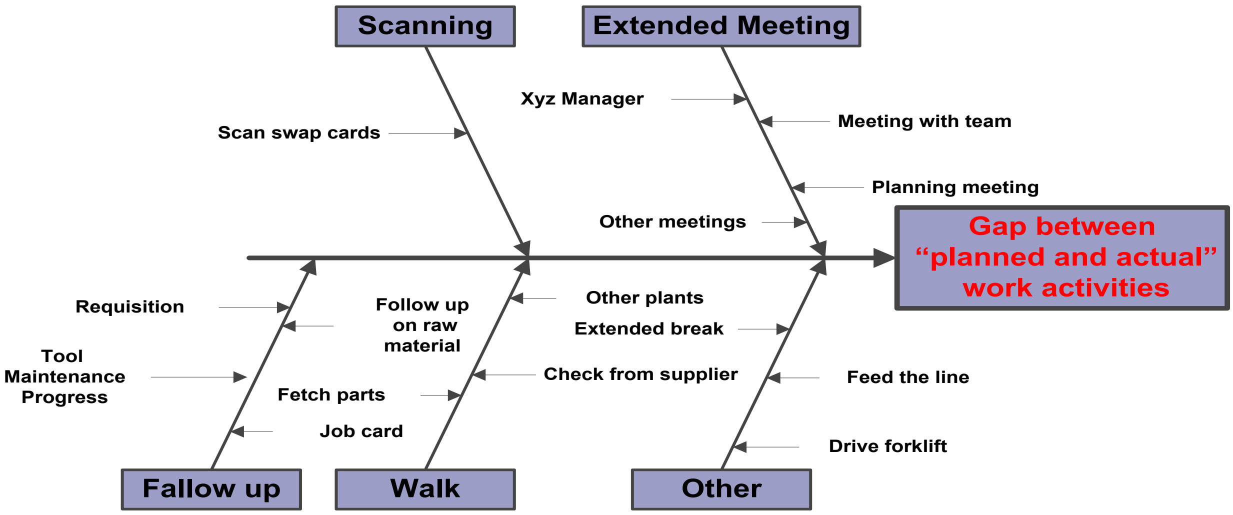

Figure 9: Cause and effect diagram for 'gap' activities

Improvement

The previous phase highlighted the waste "gap" of nearly 49% comparing to the planned activities. This figure is a significant amount that requires actions to be taken to minimize it. Looking at the data collected, Figure 4

revealed that in the majority of tasks, a number of actual shift activities are fewer than the planned activities. Meanwhile, Figure 5 showed the existing unbalance between planned and actual shift activities.
To reduce this wide "gap", the research targeted the "***out of line manager' control***" activities first. This is because unplanned activities impact the line manager's efficiency, the work predictability, even the reliability of the system. There is therefore a call to standardize the work procedure, system and schedule in order to alleviate fluctuation. In the Table 4 below, the research has painted the current work situation and proposed improvements for ***"out of line manager' control"*** activities and "***within-line managers' control***" activities conducted by Line manager "XY".

Table 4: Daily activities 'gap' for line managers' Improvement plan

TYPE OF GAP	ACTIVITIES	CURRENT	IMPROVEMENT
OUT OF LINE MANAGER CONTROL	**Meetings**	Meetings were by far the biggest time waster representing 42% of all the "gaps". Meetings were held twice a shift, in the beginning of the shift and after lunch. Furthermore, impromptus meetings were held during the study.	The maximum meeting time with other management staff should be 15 minutes. An agenda was sent by the manager prior. Only issues requiring corporate discussion needed attention. The remaining issues needed to be raised either telephonically or by email.
	Scanning	Scanning machine had swapping problem that prevented cards from swapping duly. Causing time wastage and loss in productivity.	Due to the sensitivity of such equipment and the time being wasted, new scanning equipment was placed to avoid further wastage of productivity.
	Follow-Up	The Line Manager wasted time on requisition, looking for resources such as gloves, masks, pens, books, etc. Follow up included also collecting missing "job cards" or following up on tool maintenance progress.	Line Manager to ensure that all relevant information and tools needed are put in place before shift commencement. Other activities such as following up on job cards or tool maintenance progress were handed over to line feeders, line operators under the supervision of the SL. A standardize process was developed in order to create a working process.
WITHIN LINE MANAGER CONTROL	**Walk**	The Line Manager during the two days studied, travelled to fetch stocks from suppliers, walked to other plants also walked to fetch the parts from WIP storage. The LM also stops on shop floor to check the control-sheet online and attend production issues.	The fetching of stocks from a supplier was scheduled once a week and done in rotation by every Line Manager. In a new standardized process developed, the line feeder was allocated parts from the WIP storage. Email and telephone were done to reduce travelling.
	Other	Time was wasted by LM driving forklift, and feeding line. Another area of waste including Extending tea break.	Standardized process was developed in order to divide and allocate jobs to operators, line feeders, forklift driver and others.

Control

To ensure that the "gap" is reduced from 49% to the predicted figure close to 0 %, the primary research goal was to examine the reason for the large "gap" as stated in Table 3 and Figure 8. Both Table and Figure have given ways for the Line Manager's work process improvement. As stated by Baraka et al. (2019), 'with leadership, come responsibility, competition, accountability and reward'. Therefore, a standardized process was developed from the exposed areas leading to time and productivity wastage. The new working procedure was not only drafted and branded at the view of all line operators, leaders, feeder, etc., but training was also administrated to all employees involved on the line. To improve the LM work process in a "***out of Line Manager' control***", meeting was limited to decision that requires consensus. Any direct orders from hierarchy were now delivered either in person or via intermediaries or by telephonic or email means. Other "***out of Line Manager' control***" activities such as scanning" required replacement while the "follow-up" process, regularly used by the LM during the two days study was minimized by standardizing the LM work process. In "***Within Line Manager' control***", activities such as walking to various places for various reasons were a key cause of wastage. Reallocating of tasks to various team members permitted a line balancing. Finally, the remaining "gap" involved extended tea break, driving forklift or feeding the line. Just as the previous activity, a standardized process using line balancing was developed and the Line Manager (LM) productivity was maximized.

Conclusion

The intent of this research was to reduce the 49% "gap" between Line Manager's planned activity and completed activities "***within the Line Manager Control***" and "***out of the Line Manager control***". A two days' time study was conducted, and the outcome has revealed "gaps" needing improvements. Among them included meetings, walking, requisition, scanning and other were the main reason of money and time wasting. Six Sigma DMAIC methodology was used with the objective of defining, measuring, analyzing, identifying, improving and controlling the Line Manager's productivity. Among the 'gap' activities listed, some activities were classified as "***within the Line Manager control***" while the remaining were viewed as "***out of the Line Manager control***" in Figure 8. Although no additional time was given for the implementation of this research outcome and improvement proposal, this research shows that DMAIC Six Sigma in Lean Manufacturing can offer organizations a practical way of increasing workers efficiency and reducing wastes especially during this challenging time of the pandemic of the Covid-19.

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