THE USE OF DMAIC SIX-SIGMA METHODOLOGY FOR DISPUTES RESOLUTION IN A PACKAGING COMPANY

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ABSTRACT

Industrial engineering plays a vital role in production improvement and the optimization of systems. With the growing impact of globalization, championing the production of quality goods and systems is key to survival. Another notable effect of globalization is the rise of work-based conflict in recent years. This study intends to use DMAIC six-sigma in resolving these work-related conflicts. After the quality assurance staff raised complaints in regard to work overload and salary increases, management decided to use work study to evaluate these claims. The results of the case study highlighted a number of challenges including breakdown in communication between hierarchies and the lack of quality assurance standardized work processes. The study recommends the restructuring of work tasks and systems in order to optimize workers' productivity and improve motivation.

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1 INTRODUCTION

Globalization is a phenomenon that has affected people differently in diverse spheres of life [1] [2]. "Globalization is a powerful force that cannot be denied, as it has brought positive facets to some parts of the world, however, conversely, it has also threatened life, in a broader sense" [3]. According to Pasricha [4], globalization is a state whereby national boundaries turn totally porous with respect to the movement of goods and capital and, to an extent, porous with respect to people, which are viewed in this context as cheap labor or cheap human capital. Apart from its impact on state boundaries and association with movement of goods and capital; globalization has led to the rise of internal conflicts between hierarchies in various industries around the world. This research used Six-sigma as a tool to resolve the rising conflicts and reduce the impact on company productivity. Six-Sigma is a highly disciplined process that enables world-class quality and continuous improvement methods to achieve the highest level of customer satisfaction [5].

The implementation of a Six-Sigma methodology aims at achieving error-free business performance, focusing on improving quality by helping organizations produce products and services better, faster and cheaper [6]. In order to achieve Six-Sigma level quality, in relation to the study objectives, Six-Sigma provides an improvement framework known as Define-Measure-Analyze-Improve Control (DMAIC). A complaint was raised to top management regarding a dispute concerning Quality assurance (QA) staff, their supervision and their service departments (Printing, Extrusion and Lamination) at a flexible packaging company in Durban.

The study aims was to use six sigma tools in resolving workplace conflict through the following objectives:

- Definition of the QA staff's daily and individual activities;
- Measurement of QA personnel's job performance;
- Analysis of each QA staff member's daily and particular activities, performance and complaints;
- Based on the outcome of the analysis, highlight potential areas of improvement;
- Proposing mechanism for sustaining the improvement.

2 LITERATURE REVIEW

2.1 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 [7]. DMAIC problem solving strategy relies on five phases: Define Measure, Analyze, Improve and Control in order to improve, and Pyzdek [6] described these phases as follows:

- **Define** phase - covers 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.

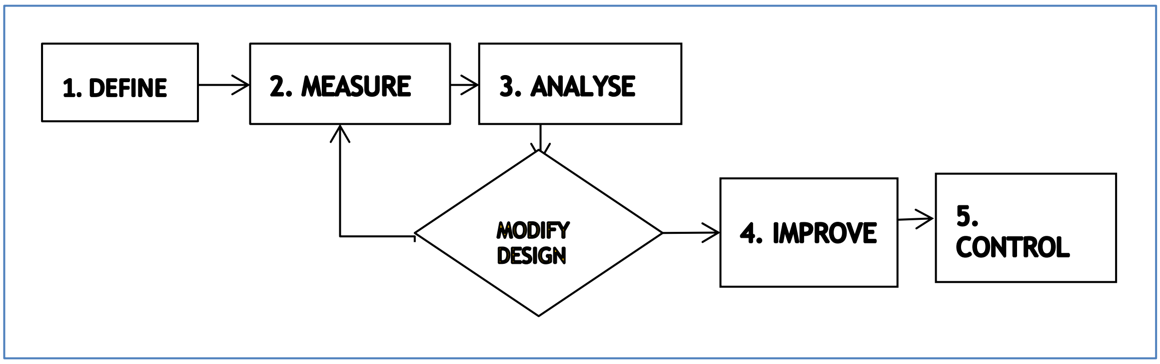

Figure 1: DMAIC process flow chart

DMAIC methodology guides the project team from the project definition (Define) to maintaining the results (Control) [8]. According Jones [9], 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.

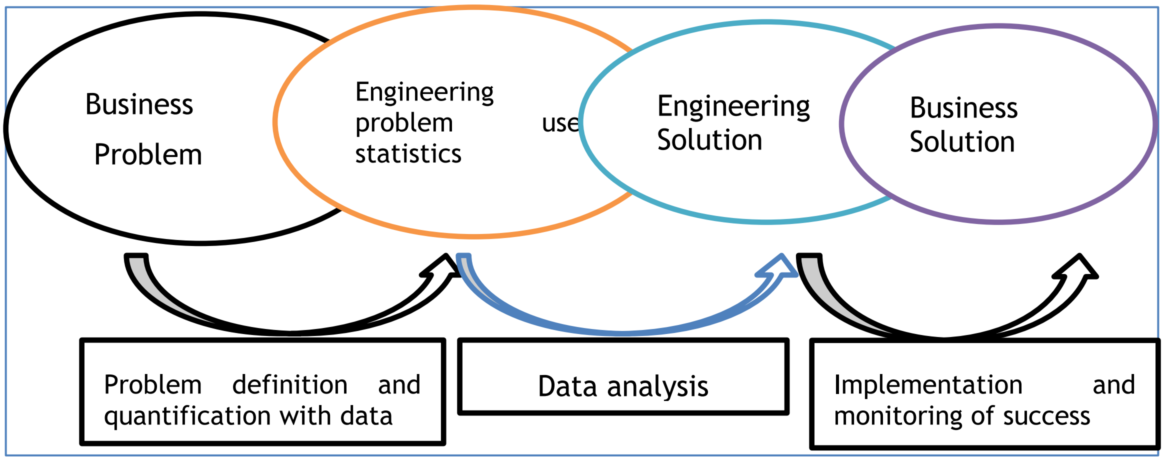

Figure 2: Role of industrial systems engineering thinking and methods [8].

Motorola USA proposed a meticulous six-sigma tool and data-driven methodology with the aim of generating a quasi-perfect production processes that would result in no more than 3.4 defects per 1 million opportunities as per the Table 1. It is vital to determine which elements in Six Sigma (SS) make it effective, but one of SS role is a structured improvement procedure and focus on metrics which contribute to quality management, and this improvement is found under DMAIC [10]. It is also similar to one of the well-known methods established by Juran called Plan-Do-Check Act (PDCA). While some argued that DMAIC method is a new method, it is easy to recognize that it is a revised version of well-known problem solving methods such as Plan-Do-Check-Action (PDCA) and Plan-Do-Study-Action (PDSA). Both PDCA [11] and PDSA [12] emphasize on a structured method toward problem solving and use similar tools and techniques as the DMAIC. The only difference is the addition of the Control phase in DMAIC. However, it can be argued that applying PDCA or PDSA is never a single cycle matter, the iteration of multiple cycle means an implicit control phase must be in place.

Table 1: Data-driven methodology proposed by Motorola, USA

Sigma(σ) Level	Sigma (with 1.5σ shift)	DPMO (Defect per million)	Percent defective	Percentage yield	Short-term C_{pk}	Long-term C_{pk}
1	−0.5	691,462	69%	31%	0.33	−0.17
2	0.5	308,538	31%	69%	0.67	0.17
3	1.5	66,807	6.70%	93.30%	1	0.5
4	2.5	6,210	0.62%	99.38%	1.33	0.83
5	3.5	233	0.02%	99.98%	1.67	1.17
6	**4.5**	**3.4**	**0.00%**	**9**		

2.2 Work Study definition and impact

According to Cheevakasemsook & Yunibhand [13], 'work study is a management service based on techniques such as method study and work measurement'. Both method study and work measurement are used in the examination of human work in all its contexts and that lead to the systematic investigation of all the resources and factors which affect the operation efficiency [14]. In order to achieve the work study objective, nine steps are vitally important [15]. These steps are subdivided into three stages as stated in the Figure 3, Figure 4 and Figure 5. The first stage as shown in Figure 3 represents the first three steps called "primary stage". The primary stage of the work study consists of selecting the study focus, recording of relevant data and breaking down of operations into elements.

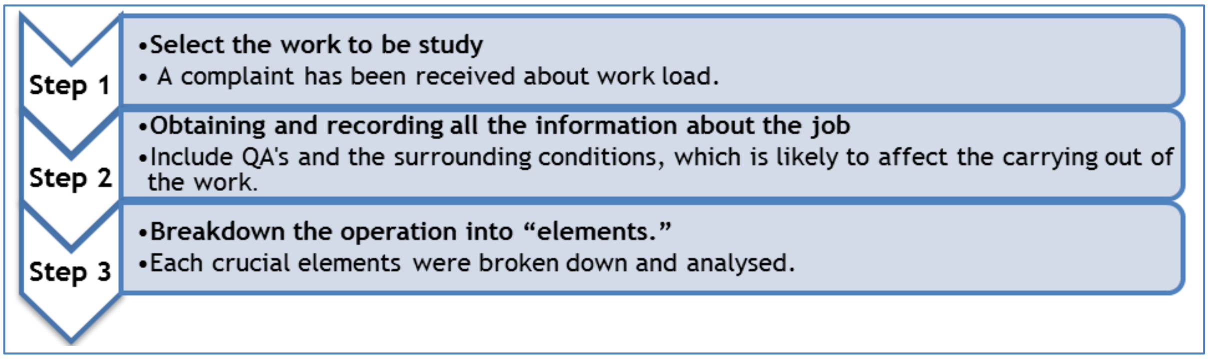

Figure 3: Primary work study stage

The second stage measures time taken to perform each operation recorded in the first stage. Then an assessment of the operator effectiveness is done followed by the adjustment of the observed time by rating factor. The secondary stage shown in Figure 4 is composed of the following:

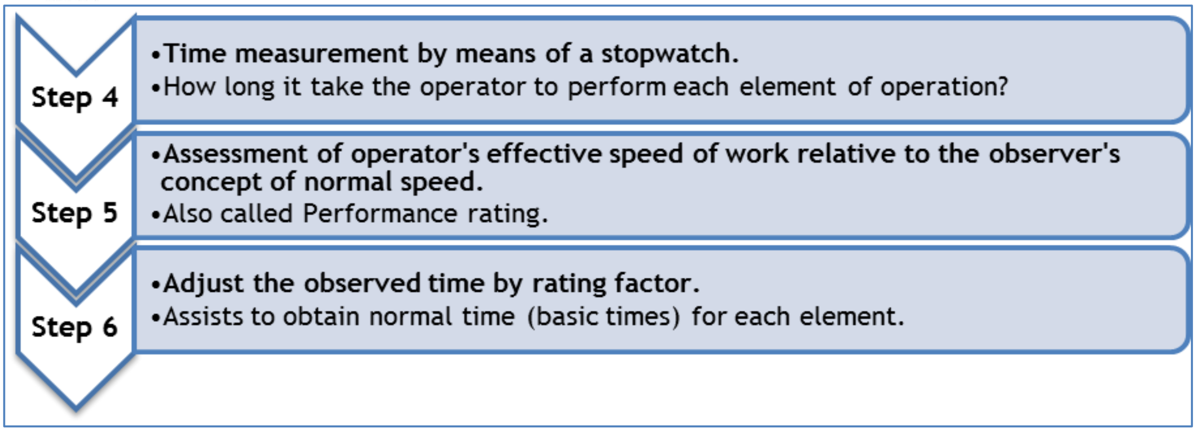

Figure 4: Secondary work study stage

Figure 5 represents the third and final stage which sums the normal times for each element and determination of the "standard time" for an operation. The third stage concludes the process and is characterized by reviews of standards whenever necessary. The tertiary work study stage is composed of the following:

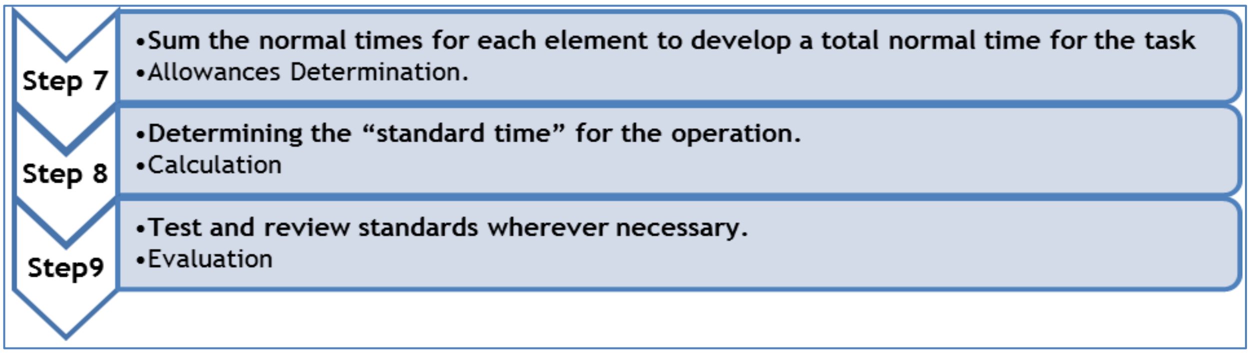

Figure 5: Tertiary work study stage

3 DATA COLLECTION

3.1 Flexible packaging company processes and QA job procedure

The Flexible packaging corporation comprised of eight printing machines (one of which is a flexo printing machine), ten lamination machines and four extrusion machines. Other machines such as the rewinding machines, slitting and packaging are not included on the study process. The role of the Quality Assurance department was to assess the quality of each batch manufactured from the printing, the lamination or extrusion machines. These machines were run by operators and each had one or two assistants depending on the work order and machine specification. All these operations required meticulous care in order to minimise wastage and customer complaints.

Quality Assurance Officers (QAOs) roles include collecting samples for quality clearance, from the machine of each reel before and after every operation (printing, lamination and extrusion). Production is executed in two shifts (8 hours and 12 hours) and each QA personnel per shift was allocated a machine for clearance, certification and recording the testing results to the JDE system for traceability and accountability.

The QAO's current job procedure consists of (1) travelling to the production line, (2) collecting the reel sample before printing. From the comfort of their laboratory, QAOs' testing procedure consists of the following: (3) oil testing, (4) ink solid testing, (5) Gas

Chromatography (GC) verification, (6) pressure test for foil, (7) bond strength of paper lamination, (8) heat resistance testing for ink, (9) extrusion coating mass, (10) adhesive radio and many more.

Table 2: QA service department and machine per section

QA/SHIFT	SECTION	LAMINATION	PRINTING	EXTRUSION	LAM
QA1	Section 1	L2	P11	E3	LA7
QA2	Section 2	L7	P10	E1	LA3
QA3	Section 3	L6	P6, P9	E7	LA5
QA4	Section 4	L8	P1	F1	LA4
QA5	Section 5	L1	P13, P8	E8	LQ3

The department is composed of 16 QA personnel, with five members of staff being rotated in both 8 hours and 12 hours shifts. Each QA staff member has a working section in the QA laboratory, as shown in Table 2. Table 2 also shows that each QA staff in an allocated section is responsible for quality clearance of at least one lamination machine, one printing machine, one extrusion machine and one LAM depending on machine production scheduling.

Figure 6 highlights the layout of the plant, specifically the locations of different machines as well as the layout of the QA laboratory. Quality Assurance Lab shown in Figure 6 includes the layout of the QA work sections (represented by 1, 2, 3, 4, and 5) and computers (represented by C1, C2, C3 and C4). Figure 6 also shows the daily itinerary of each QA per session as per Table 2. For instance, the QA in Section 1 (Itineraries shown in red arrows) services the printing machine (P11), the lamination machine (L2), the extrusion machine (E3) and the LAM (LA7).

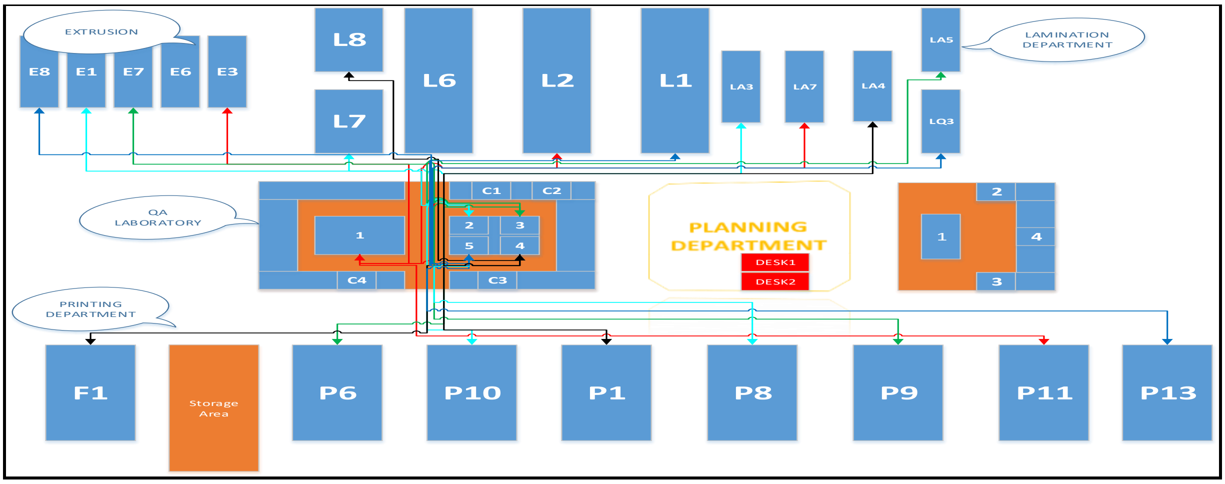

Figure 6: Layout of each department location with each section duties

The flexible plant being studied ran on 8 hours shifts (6am - 2pm; 2pm - 10pm and 10pm - 6am). The QA department however operates in two shifts system (12 hours shift and 8 hours shift). Of the five testing sections composed in the lab, two QAOs operated for 12 hours shift (6am-6pm and 6pm-6am) while the remaining three QAOs operated for 8 hours shift (6am - 2pm, 2pm - 10pm and 10pm - 6am). For diligence purposes, the QA routine work activities were observed in line with their job procedures and the production planning. This preliminary observation led to time study being conducted to all 16 QA members. The study was piloted for both 8 hours and 12 hours shifts QA personnel. Figure 7 shows that 2 QAOs were studied from section 1 (QA11 and QA12); another 2 were studied from section 2 (QA14 and QA15); 5

were from section 3 (QA1, QA2, QA3, QA10, QA13); another 5 from section 4 (QA4, QA5, QA6, QA7, QA16) while the remaining 2 QAOs were studied from section 5 (QA8 and QA9).

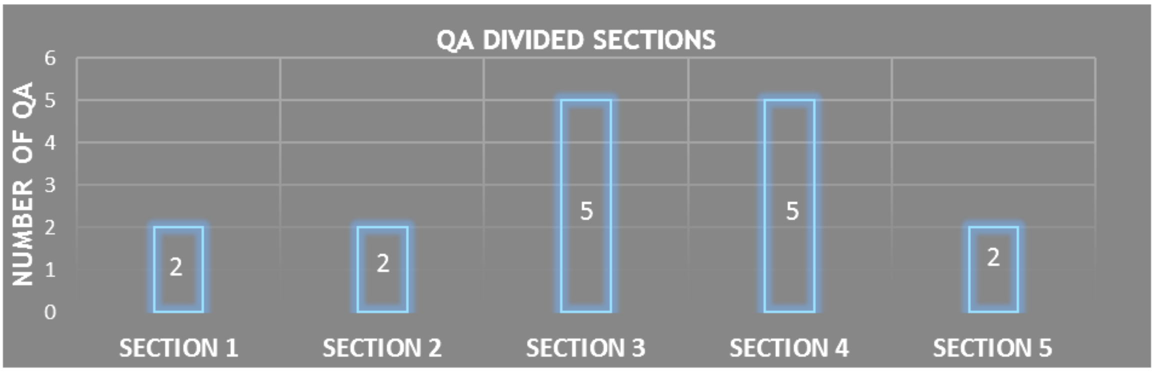

Figure 7: Number of QAOs studied per Section

3.2 Planning Department

The planning department is responsible for the production planning. On daily basis, if the maintenance department declares a machine to be fit to operate, the planning department assigns a work order to the machine operator and to QA personnel. The work order is offered for every job with all necessary information required to run that job.

There are factors worth noting that precede a successful production planning and scheduling; chief among them are the availability of material in the storage. Other factors include the (1) quantity of product to be produced, (2) machine availability or (3) machines not operating in their optimal capacity. Furthermore, factors that could lead to unsuccessful production is (1) machine speed being below the estimation and (2) the machine set up time taking longer especially when production variation is higher. Another factor that could lead to unsuccessful job production is long wait by machine operator waiting product be cleared for production by QAOs.

4 RESEARCH METHODOLOGY

Six-Sigma DMAIC has an ability to help organization make more money by improving customer value and efficiency [8]. With the research using DMAIC (Define, Measure, Analyse, Improve and Control) as framework to achieve the study aim, each step of the Six-Sigma tool had to be applied to the study to resolve the current disputes starting from the “definition” of the QAOs daily routines starting from the beginning of the shift to its end. The definition phase of Six-Sigma DMAIC isolates the top causes behind the CTQ (Critical-to-Quality Characteristic) or metric. “Define” objective also includes the work equipment used by the QA being studied, the process as well as the standard working procedures if existing any.

The following step was the “Measurement” of how long it takes for a QA to conduct his or her daily routines in an 8 or 12 hours shift. “Measurement” phase in Six-Sigma DMAIC is a crucial as it assists quantify numerically and exponentially each QAOs values. With all parameters included, “measurement” of the QAOs daily activities assists the relevant authorities to have in their possession facts allowing them to either support or debunk the QA request for more financial incentive as a consequence of being overworked. After measuring Critical-to-Quality (CTQ) characteristics of the study, the next phase involves analysing those CTQ. As part of the “analysis”, data gathered were analysed using an Excel spread sheet. Time Measurement Sheet was used to determine the average cycle time. From the cycle time, periodic operation, idle and tea time were calculated. Graphical representation of the results was used to identify critical cases.

The next step for the six sigma DMAIC framework is to “improve” the current work practices and environment. Improvement of the QAOs’ daily routine was based on the outcome of the research analysis. It should be noted that DMAIC is a cycle that can be repeated as long as improvement is needed. After improving the existing system, the final phase includes "controlling" the improved system in order to ensure lasting results and sustained changes. The best controls require little or no monitoring, such as process design or irreversible product changes, but usually there are also setup procedures, process setting, and other improvements that will necessitate monitoring and specific daily operation requirements [16]. Steps need to be taken to ensure that the process will not revert back to the "old way" of doing things.

5 RESULTS

As indicated in the objectives of the study, six sigma DMAIC steps were applied in order to achieve the needed results.

5.1 Define

The first step for the six sigma DMAIC process is QA complaints definition. A complaint was launched by QA personnel to the relevant authority with regards to their current working conditions, their relationship with their foreman, as well as their relationship with the various service departments (extrusion, printing, planning and lamination). According to the QAOs' complaints, their working conditions were characterised by "excessive work overload". They were convinced that servicing 5 machines per section daily is overwhelming especially when counting the frequent back and forth travelling between machines for samples collection. The other key issues of complaint were the salary imbalance between departments. According to the QAOs, machine operators, although supplemented by assistants, have less responsibility while being ahead in the company hierarchy and salary ranking.

Recently, further responsibility was demanded from the QAOs, causing further divides between QAOs and their management. The management requested capturing of the results of every test conducted by QA on the Oracle's JD Edwards software at every section in addition to their existing activities. However, the QAOs argued that there was insufficient time to yield to the managers' demand due to the lack expertise in operating the system, coupled with slow and insufficient computers with the JDE system in the lab (only 4 computers for 5 QAOs).

5.2 Measurement

Time study was conducted on each of the 16 QAOs using among other devices, a stopwatch. After weeks of observations, QAOs' daily activities were broken down and these activities were recorded per section as detailed in Table 2. The stopwatch was used to determine how long it took to fulfil each activity.

5.2.1 QAOs Routine and Particular Activities observed

As a key step to the time study, QA activities from each section were observed and recorded. As shown in Table 3, some activities were routine activities while others were particular. Table 3 also shows the findings of the observation conducted on the QAOs in all the lab sections. The observation also revealed how often "#" those activities took place.

Table 3: Daily Quality Assurance activities per Section

Section	#	Section 1	#	Section 2	#	Section 3	#	Section 4	#	Section 5
QA's Studied (16)	2	11, 2	2	14, 15	5	1, 2, 3, 10, 13	5	4, 5, 6, 7, 16	2	8, 9
Routine Activities Observed	2	Job Preparation	2	Job Preparation	5	Job Preparation	5	Job Preparation	2	Job Preparation
	2	New Chart filling	2	New Chart filling	5	New Chart filling	5	New Chart filling	2	New Chart filling
	2	Travelling to Machines	2	Travelling to Machines	5	Travelling to Machines	5	Travelling to Machines	2	Travelling to Machines
	2	Raw Material Analysis	2	Raw Material Analysis	5	Raw Material Analysis	5	Raw Material Analysis	2	Raw Material Analysis
	2	Finished Product Analysis	2	Finished Product Analysis	5	Finished Product Analysis	5	Finished Product Analysis	2	Finished Product Analysis
	2	Chart filling	2	Chart filling	5	Chart filling	5	Chart filling	2	Chart filling
	2	Tea Break	2	Tea Break	5	Tea Break	5	Tea Break	2	Tea Break
Particular Activities Observed	2	Capturing JDE	1	Planning department	1	Solving Non Conformity	2	Capturing JDE	1	Planning Department
	1	Gas Changing	1	Ratio Testing	1	Capturing JDE	1	Gas Changing	1	Gas Changing
	1	GC Resetting	2	GC Setting	1	GC Setting	1	Resetting of GC	1	Resetting of GC
			1	Capturing of JDE	1	Planning Department	2	Toilet break	1	GC Setting
							2	Solving Non Conformity	1	Solving Non Conformity
							1	Planning Department		
							3	Ratio Testing		
							1	making Photocopy		

5.2.1.1 Routine Activities Observation

Figure 8 shows that 5 sections out of 5 were routinely involved with activities listed in the "routine activities observed" shown in 3 although the machines are different in every section. Figure 9 reveals that all the 16 QAOs studied were involved the activities listed in each of the five sections.

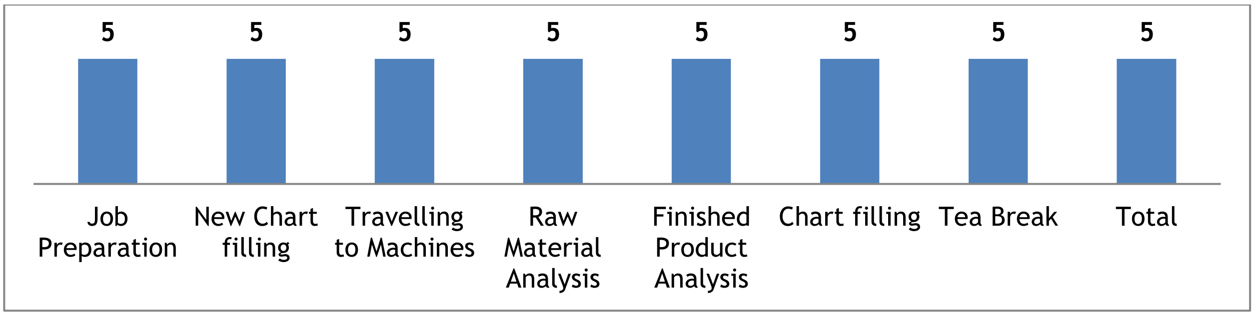

Figure 8: Daily Activities Observed per Section

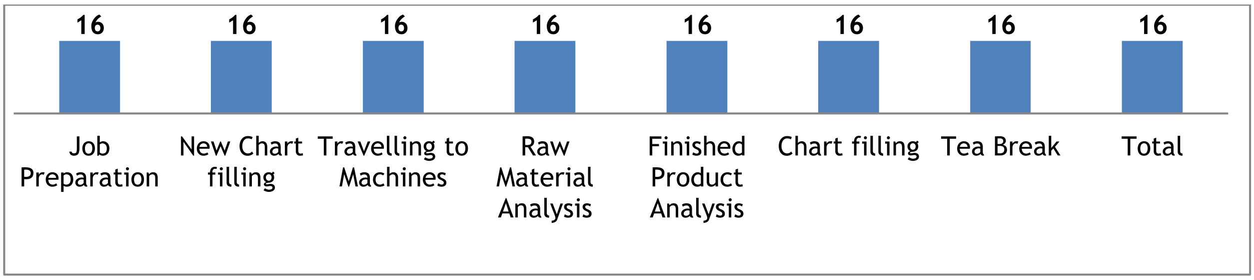

Figure 9: Daily Activities observed per number of QAOs

5.2.1.2 Particular activities Observation

Particular activities are one that occurred once after a while, often as a result or consequence of some anomaly. Particular activities observed included inquiring about missing or incomplete work orders from the planning department, gas changing, resetting of the GC, and capturing the JDE, ratio testing, solving non-conformity, GC setting and others. Figure 10 and 11 revealed that certain activities were not conducted by QAOs and did not occur in some sections.

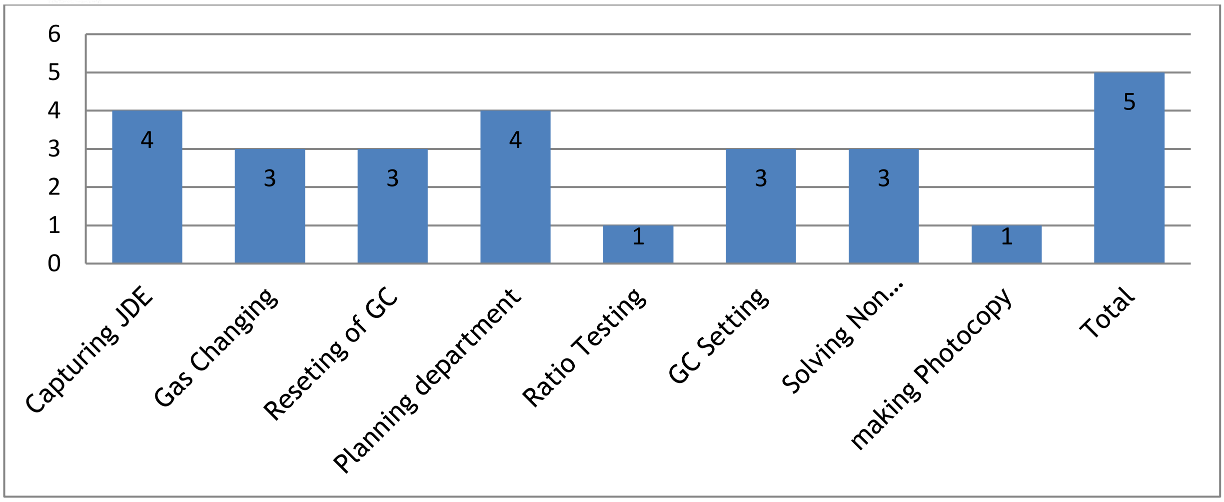

Figure 10: Particular Activities Observed per Section

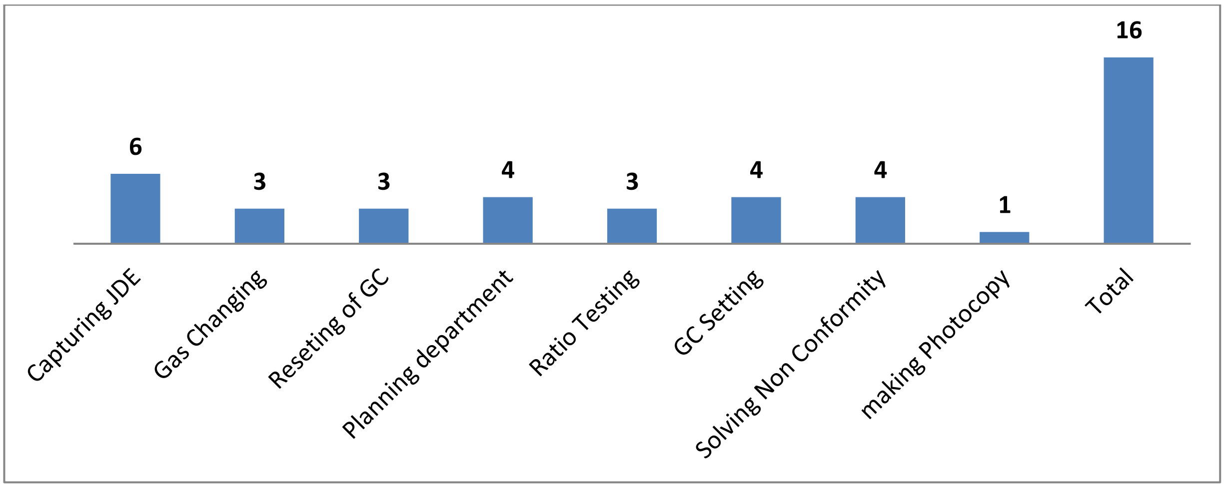

Figure 11: Particular Activities Observed per Number of QAOs

5.2.2 Time recording

From the outcome of the observation, Table 4 shows the recorded time for every activity conducted by QAOs from every section. The table below reveals the each QA periodic operation time, idle time and tea break time. Periodic operation includes preparation for the job while waiting for machines to run and work orders from the planning department. Other periodic operations include chart filling after every job, traveling to and from machines to collect raw materials, finished goods or even solving nonconformity, testing raw materials, solving nonconformity, production analysis, capturing of JDE, GC setting, Gas changing and reset, ratio test and going to planning department.

Table 4: Recorded time for each QA activity (Minutes)

QA	Preparation	Chart filling	Travelling	Raw Materials	Solving Nonconformity	Production Analysis	Break	Idle	Capturing JDE	GC Setting	Gaz changing and Reset	Going to Planning	Ratio Testing
QA1	0	15.53	16	4.68	0	255.97	70	60	0	0	0	0	0
QA2	52.42	19.89	19.67	2.45	0	302.97	18	31	0	0	0	0	0
QA3	37.3	13.37	23.84	41.85	23.75	215.63	55	55	0	0	0	0	0
QA4	60.08	30.01	23.19	16.25	0	180.2	41	92	0	0	0	9.38	5.23
QA5	92.02	2.32	39.9	15.47	0	100.99	53	108	8.1	0	18.63	13.48	0
QA6	62.99	7.11	54.72	17.89	4.18	178.75	70	45	0	0	0	0	3.16
QA7	5.37	6.6	27.92	2.54	0	63.42	73	117	0	11.48	0	0	3.23
QA8	17.67	34.79	79.83	10.23	0	178.59	83	53	0	0	0	0	0
QA9	0	45.19	76.96	6.35	0	138.49	81	34	51.34	36.59	0	0	0
QA10	0	2.18	13.85	2.2	0	64.73	62	96	22.91	0	23.79	0	0
QA11	0	11.71	60.75	5.44	0	135.68	68	118	54.08	0	0	0	0
QA12	107.99	16.28	35.85	3.77	7.38	149.07	58	25	0	9.69	43.62	32.19	0
QA13	77.25	14.63	30.49	7.69	0	159.74	77	82	0	0	0	7.1	0
QA14	92.61	10.59	26.28	14.6	0	109.63	69	53	39.94	9.27	0	5.54	10.32
QA15	60.72	9.64	29.63	16.3	0	171.01	78	71	0	16.96	0	0	0
QA16	63.75	3.71	46.76	5.31	14.46	172.12	68	84	2.1	0	0	0	0
TOTAL	730	244	606	173	50	2577	1024	1124	178	84	86	68	22

5.3 Analyse

Figure 12 shows that "production analysis" (raw material and finished good reels testing time in minutes) was the activity conducted by QAOs with the most consumed time with a total of 2577 minutes (Averaging 161 minutes per QA). While solving non-conformity (total of 50 minutes) and Ratio testing (22 minutes) were the least time consuming. Idle time (1124 minutes) and Break time (1024 minutes) came as second and third activities.

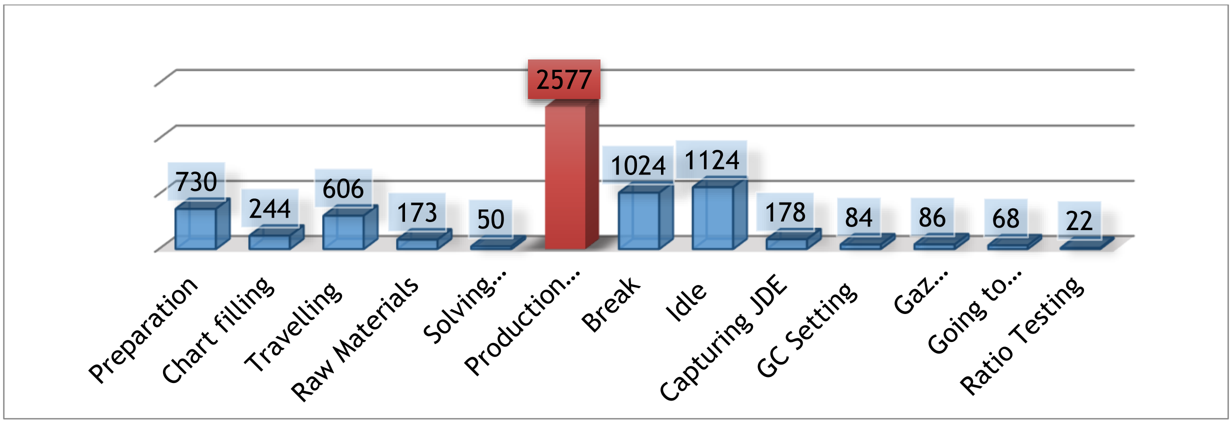

Figure 12: Recorded activities graph

Table 5 shows the sum of periodic operation time, the idle time and the tea break time per section from all the shifts (6AM to 6PM shift (12 hours), 6PM to 6AM shift (12 hours), 6AM to 14PM shift(8 hours), 2PM to 10PM (8 hours) and finally 10 PM to 6AM (8 hours)).

Table 5: QAOs Operation Time, Idle Time and Tea break (hour)

QUALITY ASSURANCE	PERIODIC OPERATIO	IDLE TIME	TEA BREAK	TOTAL (HOUR	SECTION	MACHINE /SHIFT	SHIFT
QA 1	5.83	1	1.17	8	SECTION 3	4	2 PM-10 PM
QA 2	7.18	0.52	0.3	8	SECTION 3	4	6 AM-14 PM
QA 3	6.16	0.92	0.92	8	SECTION 3	4	10 PM-6 PM
QA 4	5.78	1.54	0.68	8	SECTION 4	3	10 PM-6 AM
QA 5	5.32	1.8	0.88	8	SECTION 4	3	6 AM-14 PM
QA 6	6.08	0.75	1.17	8	SECTION 4	4	2PM-10 PM
QA 7	4.83	1.95	1.22	12	SECTION 4	4	6 PM-6 AM
QA 8	5.74	0.88	1.38	8	SECTION 5	4	6 PM-14 AM
QA 9	6.08	0.57	1.35	12	SECTION 3	4	6 AM-6 PM
QA 10	5.37	1.6	1.03	12	SECTION 1	3	6 AM-6 PM
QA 11	4.9	1.97	1.13	12	SECTION 1	3	6 PM-6 AM
QA 12	6.62	0.41	0.97	12	SECTION 5	4	6 AM-6 PM
QA 13	5.35	1.37	1.28	12	SECTION 3	5	6 PM-6 AM
QA 14	5.97	0.88	1.15	12	SECTION 2	2	6 AM-6 PM
QA 15	5.52	1.18	1.3	12	SECTION 2	4	6 PM-6 AM
QA 16	5.47	1.4	1.13	12	SECTION 4	4	6 AM-6 PM
MIN	4.83	0.41	0.3			2	
MAX	7.18	1.97	1.38			5	
AVERAGE	5.76	1.17	1.07			4	

Table 5 and Figure 13 show the periodic operation for each QAO and QA 2 had the highest operating time (7.18 hours an 8 hours afternoon shift) while QA 7 and QA 11 respectively have the lowest periodic operation time. Furthermore, Table 5 and Figure 14 reveal that QA11 has the highest "idle time" (1.97 hours for a 12 hours night shift) while the QA12 had the lowest time (0.41 hours for a 12-hour morning shift). As for the break time, Table 5 and Figure 15 show QA 8 as the Quality Assurance personnel with the longest Tea Break (1.38 hours for an 8 hours morning shift). It should be noted that tea breaks are used smoking QAOs as smoke break.

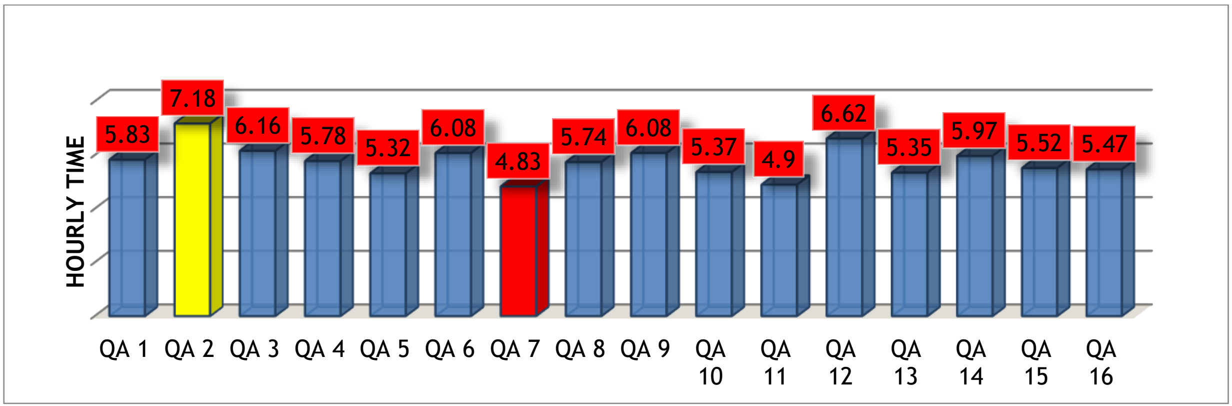

Figure 13: Periodic Operation per QAO Analysis

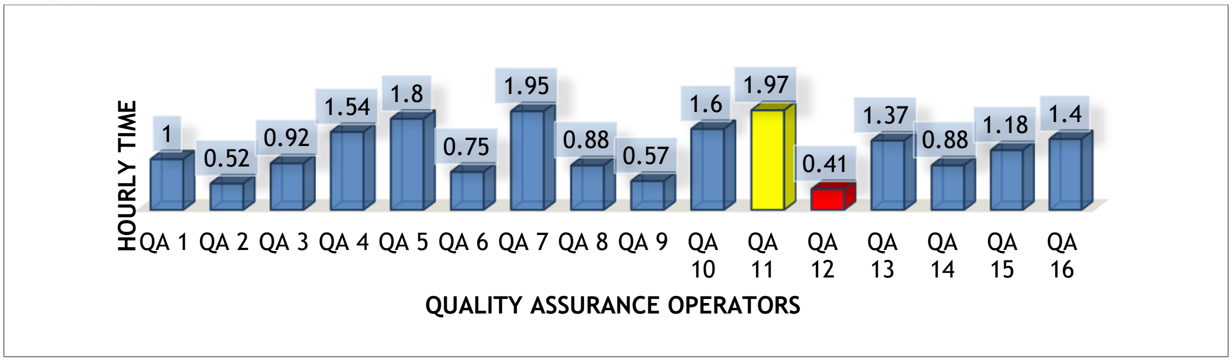

Figure 14: Idle Time Analysis

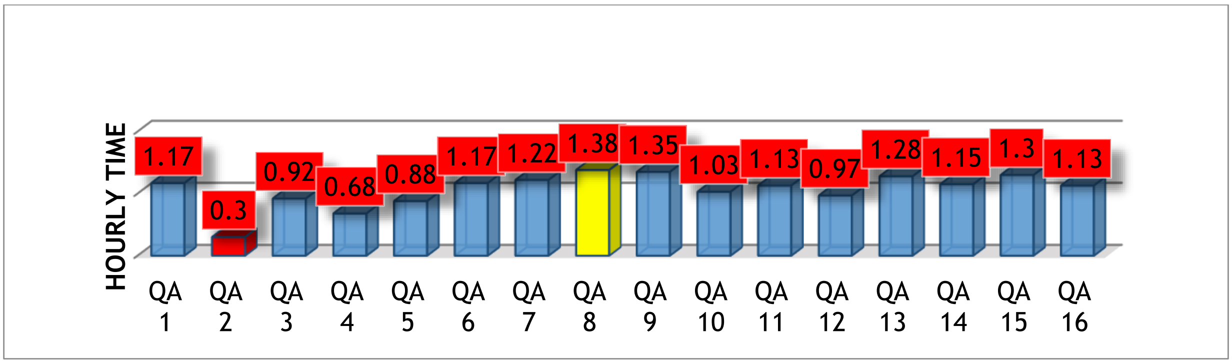

Figure 15: Tea Break Analysis per QAOs Analysis

Table 6 shows number of QAOs studied per section in every shift, including the average periodic time, average idle and average tea break per shift. According to Table 6 and Figure 16, the 12 hours shifts (both 6AM to 6PM and 6PM to 6AM) had the highest number of QAOs studied (5 QAOs for each), while all the 8 hours shifts (6AM to 2PM, 2PM to 10PM, 10PM to 6AM) had the lowest with 2 QAOs for each shift. Furthermore, Table 6 and Figure 16 reveal that the highest average periodic operation time was from the 6AM to 2PM shift, followed by the 10PM to 6AM shift. The 6PM to 6AM shift had the highest idle time, followed by the 10PM to 6AM shift. Finally, both Table 6 and Figure 17 conclude that the Break time is the highest in 6PM to 6AM shift, followed by 6AM to 6PM shift.

Table 6: QAOs Operation Time, Idle Time and Tea break per Shift (hour)

SECTIONS	No of QA	6AM-6PM	6PM-6AM	6AM-2PM	2PM-10PM	10PM-6AM
SECTION 1	2	QA10	QA 11			
SECTION 2	2	QA14	QA15			
SECTION 3	5	QA9	QA13	QA2	QA1	QA3
SECTION 4	5	QA16	QA7	QA5	QA6	QA4
SECTION 5	2	QA12	QA8			
TOTAL QAs PER SHIFT	16	5	5	2	2	2
AVERAGE PERIODIC TIME		5.90	5.27	6.25	5.96	5.97
AVERAGE IDLE TIME		0.97	1.47	1.16	0.88	1.23
AVERAGE TEA BREAK		1.13	1.26	0.59	1.17	0.80

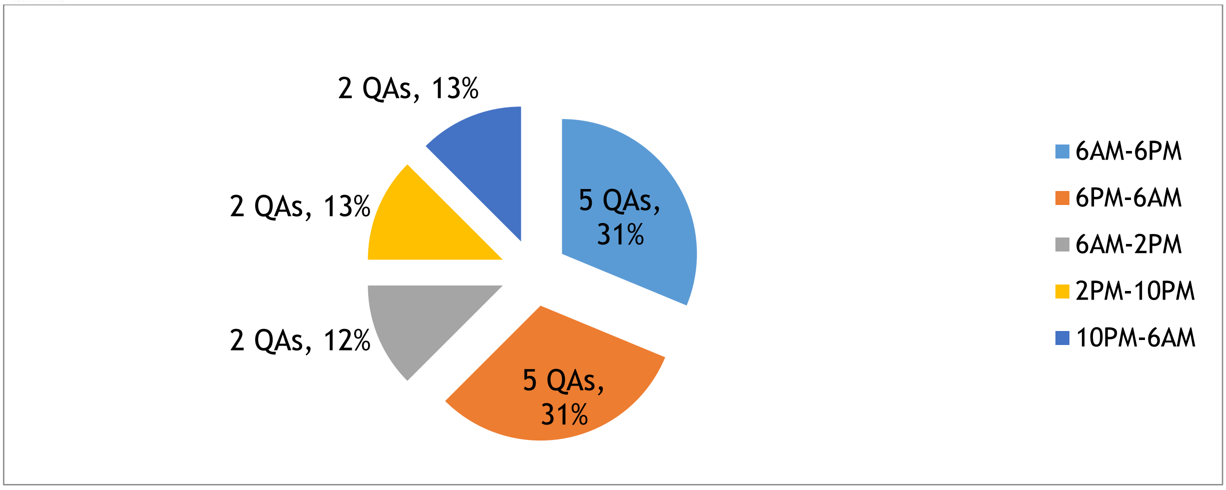

Figure 16: Number of QAOs studied per shift

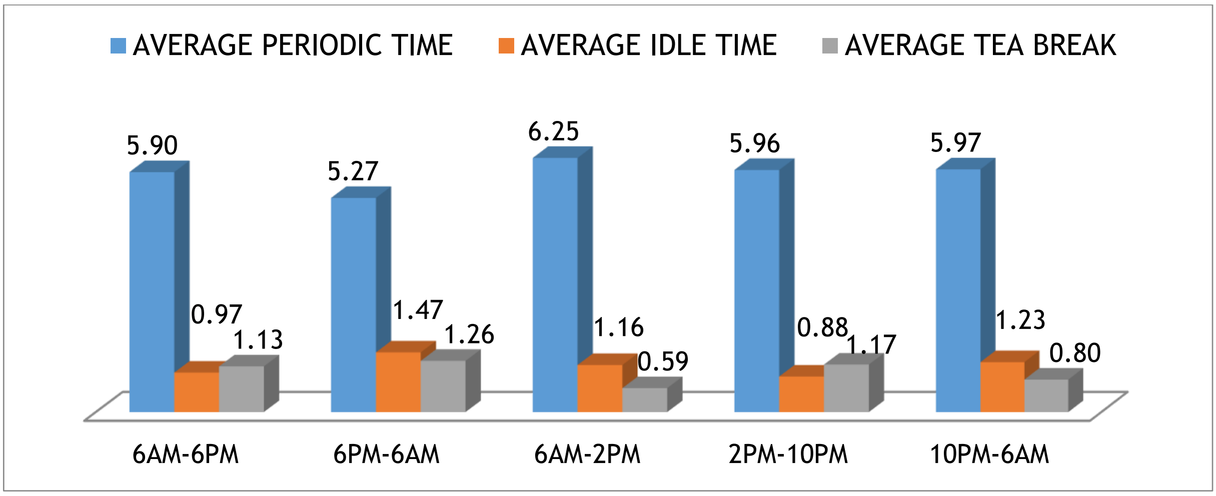

Figure 17: Time analysis per shift (hour)

5.4 Improvement

The analysis that was conducted led to issues causing disputes being highlighted. After detailed analysis, areas that were prioritised for improvement in order to resolve the current disputes are: (1) the QAOs staffs in comparison to their peers, (2) their daily activities and finally (3) their Performance rating and customer satisfaction. Table 7 highlights the current situations (Before) and the proposed improvements (After).

Table 7: Current situation (Before) Vs. Improvement plan (after)

BEFORE/AFTER	CURRENT SITUATIONS (BEFORE)	IMPROVEMENTS PLAN (AFTER)
QAOs staffs Vs. Service Department	Monthly salary being less than operators from service departments	Offer pay overtime for QA, restructure work activities by giving more responsibility of part quality to operators and their assistants
	No structured training, learn overtime from the most experienced	Develop of standardize work procedure for every QA working on the Lab
	Communication breakdown between QAOs, service department and QAOs management	QAOs daily activities and roles should be in line with the Job description

Daily activities	Only 6 QAOs of the 16 captured the JDE during the study. Many factors prevented capturing such as the number of machines running per section, as the job type, as the computer literacy of QAOs, and also the accessibility of the system and Lab computers.	Based on the study results, study cannot conclude after the analysis that QAOs have sufficient time to capture the JDE as per request. However, standardised work, job training as well promotion of team leadership in each shift can increase the QAOs time to capture the JDE as requested.
	Depending on the daily planning, sections and QAOs business per shift varies.	A team leader at every shift is needed for work redistribution. A team leader will encourage accountability, team work and unity for a common goal.
	Solving nonconformity is strenuous and time consuming for QA	Having a team leader per section promote communication to service departments and to QAOs management
	660 minutes was spent by QAOs travelling to machines to (1) check state of machine, (2) collect raw material reels before production and (3) collect finish goods after production	Travelling cannot be fully eradicated. Operators and assistants should be responsible of ensuring that the machine, the raw materials and finished goods are cleared before moving to the next step. QAOs should certify the machine readiness before any production occurs.
Performance rating Vs. customer satisfaction	Nonconforming products are one that had failed the Quality clearance	Clearing without delays raw materials before any production
	Daily activities includes Non-value added operation such travelling to collect samples, waiting and going for planning department for daily plan	Operators and assistant dropping the sample to the QA lab as a means of sharing responsibility. Ensuring that the daily plan is ready up on the QAOs arrival
	Performance rating in the morning (6AM to 14PM and 6AM to 6PM) and evening (10PM to 6AM and 6PM to 6AM) were the lowest. With an increased Tea breaks and idle time.	Ensure that all relevant information and tools needed for the commencement of each shift is available beforehand (work order, gloves, colour matching, etc.). A regulated break time, smoke time and other idle time is needed.

5.5 Control

For a permanent resolution of the disputes in the QAOs' laboratory, it is of primary importance that a leader is appointed for every shift for the reason stated in the improvement. With leadership, come responsibility, competition, accountability and reward. Furthermore, some activities are proven to be time wasting. It is therefore necessary to rebalance work activities, standardised the job procedure and processes then train all 16 Quality assurance staff on the new and upgraded job procedures. Any deviation of this new system, trained standard procedure, should result to disciplinary actions. Finally, improvements proposed in this study can only see success if management, QA department and all service departments show willingness to work together for customer satisfaction.

6 CONCLUSION

With the goal of accurately establishing how long it takes for each QAO to complete daily activities per section, this systematic examination of QA staffs activities has highlighted flaws. The Six Sigma DMAIC methodology would improve the effective use of time or money and set up standards of performance for the activities being carried out. Although no additional time was given for the implementation of the improvement proposal, Six Sigma improvement phase discussed the results of the analysis and underlined all areas for improvement. Future studies will possibly quantify this improvement in both financial and production terms.

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