FEDERAL UNIVERSITY OF TECHNOLOGY, AKURE
JOURNAL OF ENGINEERING AND ENGINEERING TECHNOLOGY

WORKPLACE REORGANISATION FOR PRODUCTIVITY ENHANCEMENT IN FAST MOVING GOODS INDUSTRY

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Kareem, B. and Alabi, S. A. and Lawal, A. S. (2023): Workplace Reorganisation for Productivity Enhancement in Fast Moving Goods Industry. *Journal of Engineering and Engineering Technology /17(1), 38-49*

Recieved Date- 29-10-21 **Accepted Date- 21-11-22**

Abstract
Application of lean strategy based on workplace reorganisation for productivity enhancement in fast moving goods industry has not been exhaustive. Leanstrategies were applied in many industries without providing a mathematic model to mimic the productivity improvement range from the continued workplace reorganization. In this study, a lean workplace reorganisation mathematical model was developed for determining productivity improvement in a fast moving goods industry. The organization of man, materials, machines, and money expended on material processing, goods processing, maintenance and (or) information departments of a fast moving goods production system was studied. Possible strategies of reorganizations were implemented in order to minimize losses and waiting time through removal of non-value added activities covering waste generation and plant breakdown. On this basis, mathematical model was developed based on Sigma-error proof performance ratio statistics between expected and actual output goods to measure improvement on the five productivity factors, which are availability, performance, quality, waste rate and work environment. Analysis of the data from a team of lean experts using model developed showed that the production process performed better with gradual improvement ranging from 32-100% for the 5-factor productivity measure. Results further showed that the lesser the number of factors considered in the model the tighter the range of productivity improvement outcome. This indicated that the more the number of productivity factors considered for a production process, the more realistic the improvement system.

Keywords: Workplace, reorganization, lean strategies, productivity, production resources

Introduction

Productivity involves proper selection of resources (man, material, machinery, energy, information, etc.) for the production process and optimum transformation of these resources into finished products (output, goods or services) for the satisfaction of targeted demands (Mbachu and Seadon, 2013). Productivity can be partial (one factor productivity), which considered only one or fewer resources as input or total (all factors productivity) that considered all necessary input resources (Kareem et al., 2019).

Open-loop nature of traditional production process enables excessive losses and wastes due to overproduction, equipment breakdown, unnecessary movement, re-work, and among others (Mbachu and Seadon, 2013). All these wastes needs to be checked by installing a good monitoring and control system with the target of satisfying customer demands (Adeyeri et al., 2016). A modern production system is required to have a reflection of close-loop control system to enable effective comparison of the output with the actual input resources, and cut waste by balancing, monitoring, and controlling input and output resources. The system that compared output products with input resources has enabled assessment using productivity ratio (Singh, 2018).

Yang et al. (2011) established a tool that related lean and productivity practices using empirical approach with target of improving environmental practices to support productivity. Hajmohahammad et al. (2013) extended the work of Yang et al.(2011) by developing conceptual model that integrated environment and social dimensions into traditional productivity performance metrics. Realization of high impact relationship between environmental performance on lean and productivity measures called for deep analysis of critical factors that were affected by environmental change. Martnez-Jurado and Moyano-Fuentes, (2014) provided a productivity tool of establishing linkages among lean management, supply chain management and sustainability. Possible contradictions and inconsistencies in the established linkages required a new pragmatic and sustainable productivity measure.
Pampanelli et al. (2014) and Verrier et al. (2014) established a lean and green productivity measure which integrated environmental and social sustainability. The model was limited in its application at production cell level. A robust model required to enable productivity measure in a multi-cell of large-

and medium-sized production systems. Faulkner and Badurdeen, (2014) developed a sustainable Value Stream Mapping (VSM) that considered environmental, societal and visualization factors in productivity measure. The metrics and methods utilized were opened for further improvements in the areas of human factor and workspace re-organization. Meyer and Stewart (2021) in their study provided strategies of utilizing motion and time study to measure productivity, but workplace reorganisation was not considered.

Marselli (2004), Pepper and Spedding, (2010) introduced the concept of one- to six-sigma productivity improvement measure in which three-sigma productivity was considered acceptable while six-sigma productivity was exceptionally (close to 100%) productivity. This concept rarely applied in modelling productivity improvement measure. Bendell, (2006) explored the possibility of combining six-sigma and the lean metrics to enhance productivity. The major limitation was inability of the study to provide specific dynamic modelling means of productivity measurement. Jeyaraman and Teo, (2010) analyzed the critical success factors (CSFs) for lean six-sigma implementation and its impacts towards productivity measure. In all cases modelling were not done to evaluate productivity improvement dynamism. However, Bamber et al. (2003) stressed the usage of cross-functional and expert teams for successful evaluation of productivity of production system.

Productivity index has been an important metric in Total Productive maintenance (TPM), Kaizen, Pokayoke, 5S, JIT, SMED, TQM, among other lean productivity measuring strategies (More et al., 2016; Butlewski et al., 2018). Productivity measurement based on Overall Equipment Effectiveness of a Manufacturing Line (OEEML) was established by Braglia et al. (2008) to overcome a challenge of operating individual and combined equipment simultaneously. The model, however, failed to consider workplace reorganisation and human factor dynamism in productivity measure.

In the work of da Costa and de Lima, (2002) planned and unplanned operating time were used to measure productivity performance index of a production process without considering system dynamism. Singh et al. (2013) in their study, automated the process of estimating machines' productivity index using software and hardware approach. Dynamism in the system, however, required the inclusion of environmental and human factors for robust application in a competitive environment.

A new productivity index was established by Anvari et al. (2010) to enable precise equipment productivity estimation for a competing flow process, without considering equipment productivity in isolation or combination(Oechsner et al., 2002).

The process of improving productivity of old and new machinery was given by Stamatis, (2011) using Pareto analysis to identify machinery that needed improvement most. Products version of the applied Pareto analysis was given by Guzel, (2022). In Ramesh et al (2016)'s study, SMED, 5S and six-sigma tools were applied to eliminate the root causes of poor productivity. Modified version of the lean manufacturing tool was applied to a shop floor for productivity enhancement (Irani, 2020; Tripathi et al, 2022). Anand and Relkar, (2012) utilized Design of Experiment (DoE) methodology toanalyze and optimize equipment productivity using three traditional productivity factors(availability, performance and quality). The static nature of the process limited its application in dynamic modern production environment. Ahire and Relkar, (2012) evaluated the traditional productivity factors with respect to Failure Modes Effect Analysis (FMEA). Rita et al. (2017) applied equipment effectiveness method to measure productivity performance index of production system using the three traditional factors, while Susilawati (2021) enhanced productivity of an organisation using multiple indicators based decision making criteria.

Hedman et al. (2016) applied automatic productivity measurement system to identify potential losses in a production line, while Kundgol et al. (2021) implemented Value Stream Mapping (VSM) approach at upgrading process and productivity of an industry. However, dynamism in productivity improvement required a system that wholly accounted for and mitigated all possible past, present and future loses and wastes in the production process.

Generally, in the past, productivity performances were measured mostly based on the ratio of quantity of outputs (goods/services) to the quantity of input resources (machinery, materials, energy, manpower, etc.), under rigid/flexible workplace flow system without considering production waste and human factor. Workplace reorganisation (flexibility) was applied in this study to measure the ratio of actual quantity of output (goods/services) to the expected output quantity. Dynamism of productivity improvement was modelled in line with modern production process reality targeting zero-waste and healthy working condition. Workspace reorganisation was carried out using 5S to reduce waste and bottle neck in order to optimize productivity while sigma (improvement probability) was used to automate the system by measuring gradually improvement due to work space dynamism. This has led to emergence of alternative productivity model named '5S-based sigma' (5S - σ) which was applied in a fast moving goods production system for productivity measurement and improvement.

Methods
The integration of workplace reorganization (5S) strategy to Six Sigma in the presence of productivity factors (availability, quality, performance, waste, and work environment) in the management of resources (man, material, money, and machine) was achieved through a framework developed as shown in Figure 1. In the model reorganisation (5S) of production resources was considered to have impact at gradually eliminating production (process) losses and thereby improving key productivity parameters (availability, performance, quality, work space comfortable workplace and zero-waste). The improvement (at eliminating productivity losses) attained at every set of reorganisation was represented as lean six sigma. Lean six-sigma was integrated into the model to provide system dynamism and flexibility in which 5S (Separate, Set to order, Shine, Standardize, and sustain) was deficient.

This alternative 5S-based sigma flexible tool was applied to a fast moving goods company using data collected from a team of lean manufacturing experts. On this basis productivity was measured before and after workplace reorganisation was done. This procedure was carried out in steps and covered the productivity factors considered. As illustrated in Figure 1, reorganization of the production system was considered to be gradual and continuous but discontinued on attainment of satisfactory productivity level ( ).

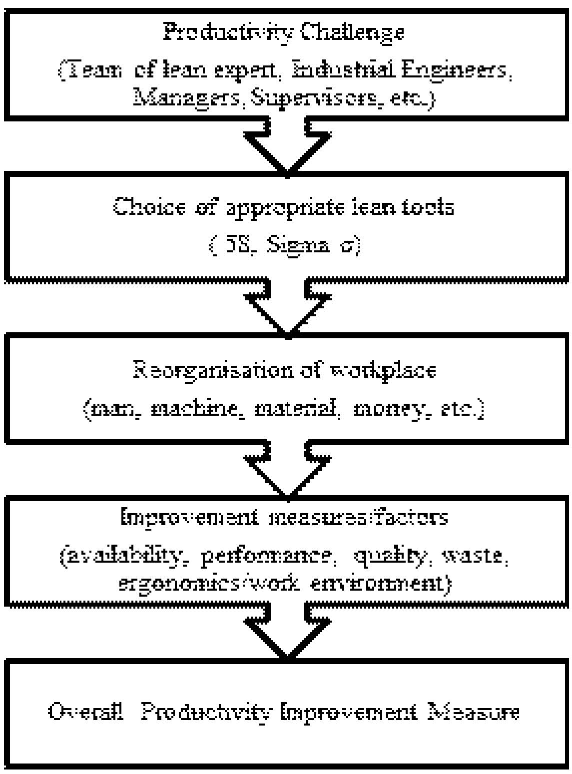

Figure 1: Overall Productivity improvement framework

The dynamic process was governed by Equations (1-3).

If

$$\left[\begin{array}{l} P_p \geq 1, \ stop, \ productivity \ satisfactory \\ 0 \leq P_p < 1, \ continue, \ improvement \ needed \end{array}\right. \quad (1)$$

$$P_p = P(1+\sigma)^x \quad (2)$$

$$P_e = 1 - P(1+\sigma)^x \quad (3)$$

where, P_p is the expected productivity from workplace reorganisation, P is the actual productivity from initial workplace organisation, σ is the sigma measure of the reorganization improvement factor, P_e is the productivity deficit, and X is time in years scheduled for next reorganisation.

P_e was determined from Equation (3) by iterating Equation (1),Equation (2) and (3), indicated the productivity P_p improvement over time X. This process continued until the sustainable target $(P_p \geq 1)$ was attained.

The parameters P_p and P were estimated using productivity ratios of productivity factors on this basis of actual and expected output goods statistics obtained at the end of each time of workplace reorganization using 5S lean tool. Productivity statistics were obtained on three-factor (availability, performance and quality) and five-factor (availability, performance, quality, workplace condition, and zero waste) bases.

The three-factor productivity measure P_3 was obtained by building on Dilworth's model in Kareem *et al.* (2019) on overall equipment effectiveness (Equation (4)):

$$P_3 = \alpha.\beta.\mu \quad (4)$$

Where: α, is the availability productivity of the plant; β, is the performance productivity of the plant; μ, is the quality productivity of the plant. By considering human comfort γ and material waste ω in addition, then Eqns. (4) was updated to form Equation (5) by combining the five factors, P_5 as:

$$P_5 = \alpha.\beta.\mu.\gamma.\omega \quad (5)$$

Partial productivity of individual factors $\theta_i(\alpha, \beta, \mu, \gamma, \omega)$ was determined from the ratio of the actual (output) O_i and the expected output (demand) D_i from the input sources (man, material, machine or money) at a given time (Equation 6).

$$\theta_i = \frac{O_i}{D_i} \quad (6)$$

The workplace environmental (temperature) change, was measured as the ratio of planned (expected) production floor temperature over actual (delivered) floor temperature. Waste productivity was measured on the basis of material quantity output (delivered) over total material input per unit time. The sigma σ was measured based on the productivity outcome of team of experts' analysis of the standardised and reorganised production floor to enhance zero waste, zero waiting time and healthy working condition. The reorganization productivity measure in term of sigma (σ) improvement factor (probability) was integrated into the model (Equation 2). The steps involved, as adapted from Kumar *et al.* (2022)'s work, in application of workplace reorganisation and standardisation (5S) to a fast moving goods industry are:

i. Sort, whatsoever activities, tools or equipment not needed in the process were visually sorted out and eliminated.
ii. Set in order, critical processing tools, parts and equipment identified were visually and neatly arranged to enable flexible and easy operation.
iii. Shine, steps (i and ii) above were made cleaned by visual reassessment to ensure perfection.
iv. Standardize, steps (i, ii and iii) above were practically applied to the process at frequent intervals to ensure that the workplace's perfect condition was maintained. This includes the application of visual control system, hazard prevention methods, plant/worker safety and quality maintenance strategies.
v. Sustain, the gains (improvements) realized from steps (i, ii, iii and iv) were recorded and applied in estimating the productivity improvement parameters shown in Equation1-6.

Data Collection and Analysis

The relevant data were collected from a fast moving goods industry, described as low-mix high-volume cigarette production factory. The data were analyzed for productivity performances (Tables 1 and 2). Table 1 for example, presents analysis outcome of the system availability performance data. Table 2 presents outcomes of analysis of productivity$_P P$for all factors,$_i\theta$ (availability, performance, quality, waste, ergonomics/workplace condition) considered. These were the actual initial productivities of the factory's workplace organisation for 8 years (2006-2013) duration (Equation 6).

Application of 5S lean tool as stated before brought about the following standardized visual changes in the factory's process flow. Sorting stage indicated that only secondary manufacturing department is critical among the departments (primary, secondary, administrative, etc) considered. The secondary manufacturing department comprises tobacco cutting, filter rod making, cigarette making, packaging, ripping, operations and maintenance units. These units were set in order by neatly reorganised, standardized and sustained them where necessary to enhance productivity.

The present process flow observed in the Secondary Manufacturing Department (SMD) of the company is shown in Equation 2, while Equation3 shows that of reorganized line process flow. The potential hazards, possible endemic diseases there from, and reorganized standard solutions provided for the manufacturing units are presented in Table 3. The mitigated waste process flow line for the units is shown in Equation 4. The comprehensive improved process flow for the SMD is presented in Equation 5. Figure 6 shows the outcome of the maintenance strategy reorganisation. Productivity improvement realised from every reorganisation carried out was computed using Equation (2) based on 5S-sigma (5S-

Table 1. System Availability Data Analysis

Year (x)	Expected Production Volume (million) D_i	Production Volume Delivered (million) O_i	Ratio $\theta_{i,á}$
2006	10,211.00	11,211.17	1.00
2007	13,541.26	13,541.26	1.00
2008	15,096.49	14,593.49	0.97
2009	14,290.13	16,290.13	1.00
2010	18,035.19	18,058.25	1.00
2011	18,996.82	18,499.26	0.97
2012	19,736.88	19,298.22	0.98
2013	20,808.32	20,341.56	0.98

Table 2 shows the comprehensive results of isolated productivity measures for availability, performance, quality, waste, and ergonomic conditions of the cigarette production flow. The results (Table 2) generally showed that performance productivity was satisfactory (≥1.0) in the first two years, quality productivity was satisfactory (≥1.0) in only second year, waste productivity was satisfactory (≥1.0) only in the last two years while productivity of the ergonomics/workplace environment was satisfactorily met the target (≥1.0) only in six of the eight years considered. It was clearly shown that the isolated productivity measures outside the stated years were not satisfactory (<1.0).Hence, production flow reorganisation required for productivity improvement to enable the system meet the desired target.

Table 2. Isolated Productivity Performance Data and Analysis

Year (x)	Availability θ_i , á	Performance θ_i ,â)	Quality θ_i ,ì	Waste θ_i ,ù	Ergonomics θ_i ,ã
1	1.0	1.0	0.97	0.91	1.0
2	1.0	1.0	1.0	0.32	1.0
3	0.97	0.87	0.98	0.70	0.77
4	1.0	0.86	0.97	0.74	1.0
5	1.0	0.89	0.96	0.94	0.99
6	0.97	0.84	0.97	0.93	1.0
7	0.98	0.86	0.97	1.0	1.0
8	0.98	0.89	0.99	1.0	1.0

Table 3 shows the identified potential hazards at SMD that were considered to adversely affect productivity and the mitigation recommendations implemented at improving productivity of the production line. In tobacco cutting unit, tobacco importing, cutting, feeding, mixing, bleeding, piping were sources of hazards in SMD. Wrong materials, plasticizer, packaging, and leakages were potential hazards at filter rod unit. Transportation, compressed air, leakages, and cleaning agents were known hazards in the cigarette making and packaging unit. Material wastes, wrong blend and infestation were hazards identified with ripping unit, while in SMD human resources/workplace environment malaria, respiratory infection, eye infection, skin infection and stress/fatigue were visualised hazards. In the first-four units material quality testing and process monitoring and control strategies were recommended and implemented at improving productivity, while provisions of enough rest time, safety gadgets, conducive workplace flexibility and clinical care centre were critical to production line/ human resources productivity (Table 3).

Table 3. Mitigating Steps for Process and Potential Hazards

Unit	Potential hazards	Mitigation recommendations
1.Cut Tobacco Unit	- Blend mixing up in feeder to maker - Tobacco pipe PVC using glues - Cut tobacco box - Imported tobacco	Test before use and monitor
2. Filter Rod unit	- Wrong materials, plasticizer - Filter rod packaging - Building leakage - Plasticizer feeding	Process monitoring and control
3. Making & Packing unit	- Transportation, wrong materials - Compressed air, building leaking - Cleaning agent	Process monitoring and control through alarm system
4. Ripping section	- Waste materials, wrong blend - Building, infestation	Process monitoring and control through alarm system
5. Human resource and workplace environment	-Malaria, Musculoskeletal -Acute respiratory infection -Diarrhoeas, eye infection -Digestive system, skin infection -Stress, fatigue, high blood pressure	Rest/break time, wear of safety shoe, goggle, foot rest, mouth/ear cover, comfortable and flexible workplace, change in posture, walking on duty, and first aid/clinical care centre.

Figure 2 shows the process flow in SMD which comprised tobacco from Primary Manufacturing Departmental store (PMD) processing, wrapping material for filter rod making, cigarette making, packaging and storage at Central Product Store (CPS). The wastes from the process were ripped and sent back to the PMD.

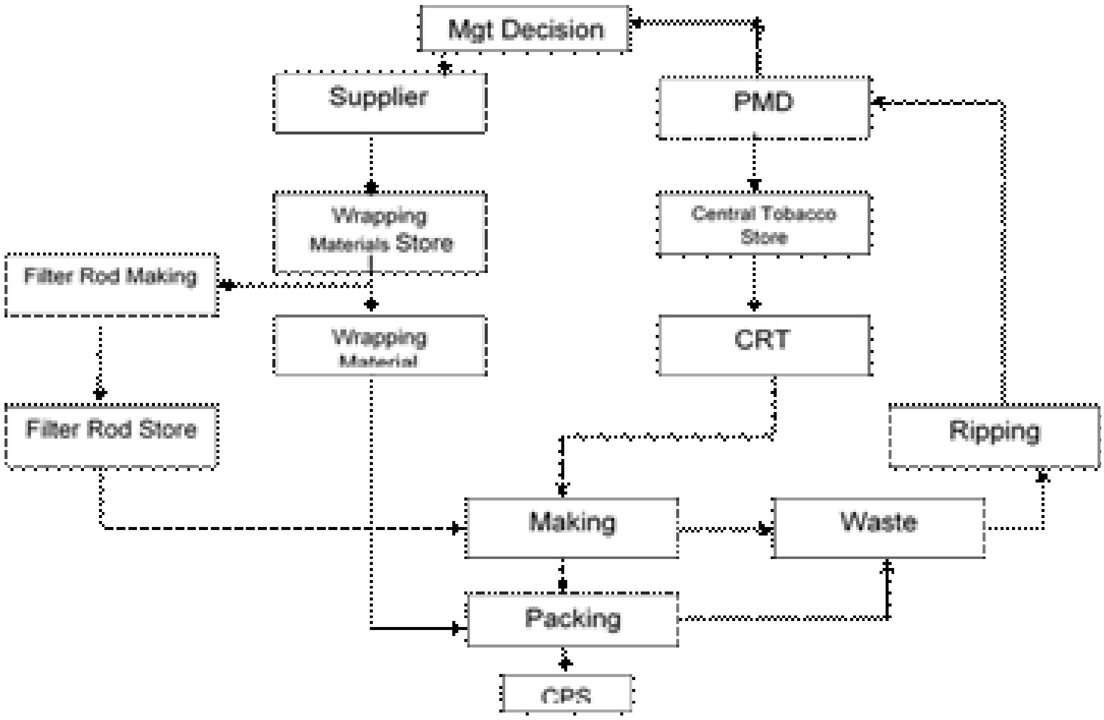

Figure 2: Process flow in Secondary Manufacturing Department (SMD)

In order to improve the performance of the process, the flow interception identified as shown in Figure 2 was resolved by reorganising the units to avoid flow interruption as shown in Figure 3.

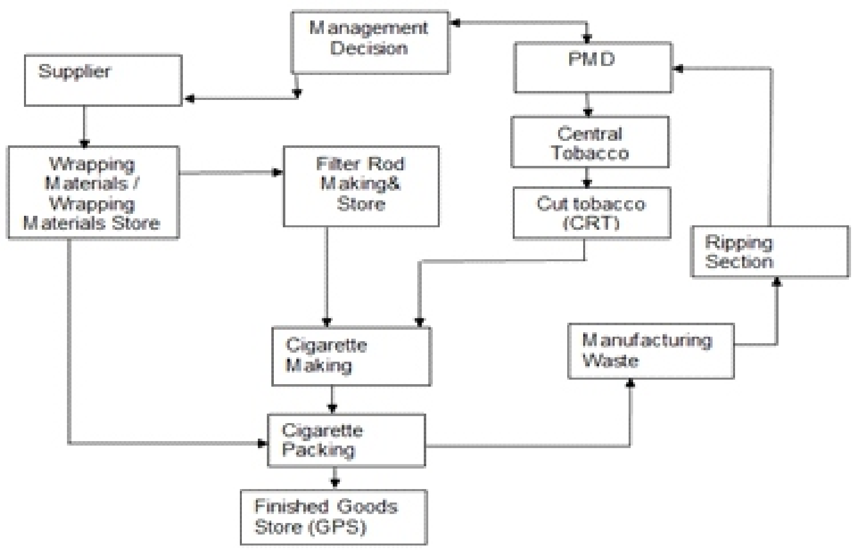

Figure 3: Improved Process flow in Secondary Manufacturing Department (SMD)

In this process filter rod making process was made closer to the cigarette making line so that packaging materials freely moved to the packaging line (Figure 3). Final wastes generated from the flow in Figure 2 were reduced to zero-waste by provision of a comprehensive recycling system comprised ripping line routed back to the PMD's central tobacco store where ripped wastes were reconditioned and controlled to ensure qualitybefore reuse (Figure 4).

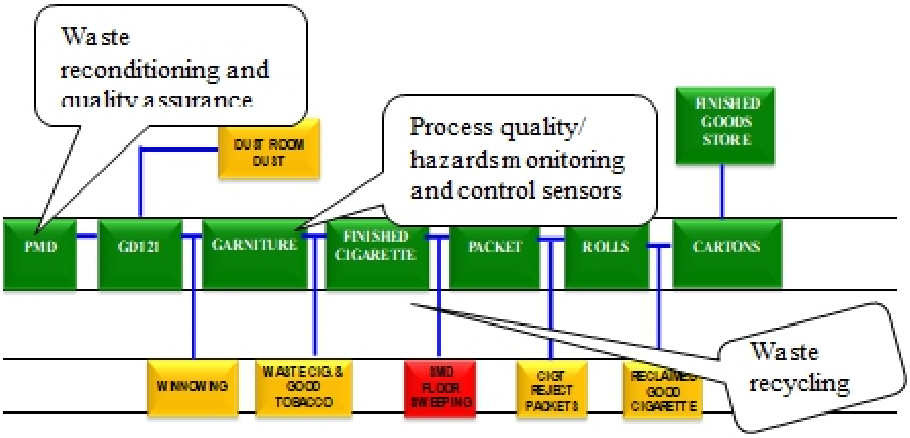

Figure 4: Waste Process Flow and Improvement Recommendations

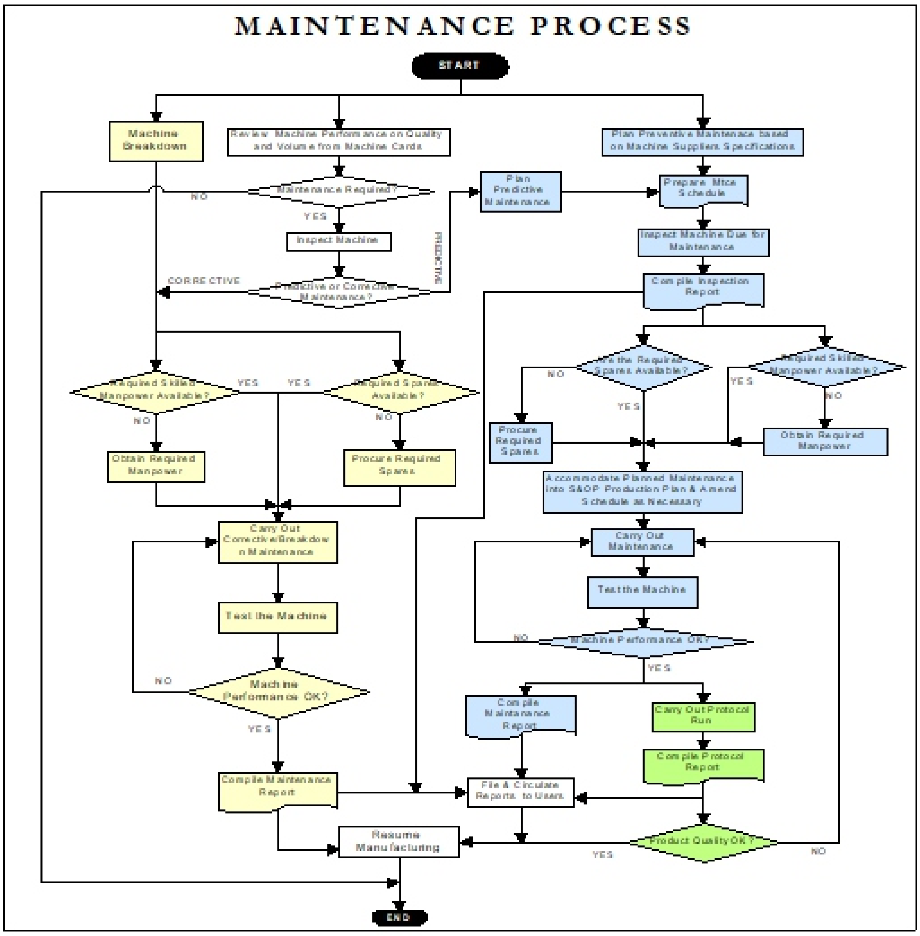

Figure 5: Strategy/Improvement of Maintenance Flow Process in the Company

In order to enhance line availability productivity, present maintenance culture of the company (Figure 5) was improved upon by automating the process through incorporation of sensors for line health monitoring to prevent pre-mature failure. Results of the previous and annually reorganised (5S) process flow productivity measured over a realizable sigma improvement probability(

Table 4.Expected Continuous Improvement P_p from the Workplace Reorganization

Improvement probability, σ /year (x	1	2	3	4	5	6	7	8
5-Factor productivity 5	0.91	**Min. 0.29**	0.45	0.64	0.83	0.76	0.84	0.87
0.1	0.32	0.35	0.39	0.42	0.47	0.51	0.57	0.62
0.2	0.35	0.42	0.50	0.60	0.72	0.87	1.0	-
0.3	0.38	0.49	0.64	0.83	1.0	-	-	-
0.4	0.41	0.57	0.79	1.0	-	-	-	-
0.5	0.44	0.65	0.98	1.0	-	-	-	-
0.6	0.46	0.74	1.0	-	-	-	-	-
0.7	0.49	0.84	1.0	-	-	-	-	-
0.8	0.52	0.94	1.0	-	-	-	-	-
0.9	0.55	1.0	-	-	-	-	-	-
1.0	0.58	1.0	-	-	-	-	-	-
3-Factor productivity 3	1.00	0.92	0.84	0.86	0.89	**Min. 0.81**	0.84	0.87
0.1	0.89	0.98	1.0	-	-	-	-	-
0.2	0.97	1.0	-	-	-	-	-	-
0.3	1.0	-	-	-	-	-	-	-
0.4	1.0	-	-	-	-	-	-	-
0.5	1.0	-	-	-	-	-	-	-

From the results (Table 4), 5-factor (availability, performance, quality, waste and ergonomics) productivity measure required higher sigma precision value for early arrival to satisfactory productivity (≥ 1.0) level than the 3-factor (availability, performance and quality) productivity level. For 5-factor system, productivity improvement attainable over the minimum (0.29) ranged from 0.32-1.0, while improvement range of 0.89-1.0 was attained over the minimum (0.89) for the 3-factor productivity measure. This implied that 5-factor system required high precision measure as compared to 3-factor system. Therefore, 5-factor productivity measure is more realistic in practice than the 3-factor measure. The expected losses results in Table 5 corroborated this finding as it was clearly shown that losses were huge across years in 5-factor productivity measure while there were fewer losses in 3-factor measure.

Table 5. Expected Losses $_{e}P$ in Improvement by the Workplace Reorganization

Improvement probability, σ /year (x)	1	2	3	4	5	6	7	8
Losses in 5 - Factor productivity	0.91	**0.29**	0.45	0.64	0.83	0.76	0.84	0.87
0.1	0.68	0.65	0.61	0.58	0.53	0.49	0.43	0.38
0.2	0.65	0.58	0.50	0.40	0.28	0.13	0.0	-
0.3	0.62	0.51	0.36	0.17	0.0	-	-	-
0.4	0.59	0.43	0.21	0.0	-	-	-	-
0.5	0.56	0.35	0.02	0.0	-	-	-	-
0.6	0.54	0.26	0.0	-	-	-	-	-
0.7	0.51	0.16	0.0	-	-	-	-	-
0.8	0.48	0.06	0.0	-	-	-	-	-
0.9	0.45	0.0	-	-	-	-	-	-
1.0	0.42	0.0	-	-	-	-	-	-
Losses in 3 - Factor productivity	1.00	0.92	0.84	0.86	0.89	**0.81**	0.84	0.87
0.1	0.21	0.02	-	-	-	-	-	-
0.2	0.03	0.0	-	-	-	-	-	-
0.3	0.0	-	-	-	-	-	-	-
0.4	0.0	-	-	-	-	-	-	-
0.5	0.0	-	-	-	-	-	-	-

Table 6 shows the summary of productivity improvement results obtained when the developed lean tool (5S-was applied to other similar industries producing wire and cable, table water, nails, beverages, plastics and confectionary as compared to that of cigarette production. The results generally showed that process hazard and maintenance were the core areas of secondary manufacturing department of the respective industry that required productivity improvement.

Table 6. Range of Productivity Improvement Across Industries

Fast moving goods industry	Core areas required improvement	Three Factor productivity improvement range	Five Factor productivity improvement range	Minimum possible improvement gained (%)	Performance
Tobbaco (cigarette)	Potential hazards and secondary production/maintenance process	0.89-1.0	0.32-1.0	32	Satisfactory
Wire and cable	Potential hazards and secondary production/maintenance process	0.65-1.0	0.40-1.0	40	Satisfactory
Table water	Potential hazards and secondary production/maintenance process	0.62-1.0	0.42-1.0	42	Satisfactory
Nails	Potential hazards and secondary production/maintenance process	0.55-1.0	0.37-1.0	37	Satisfactory
Beverages	Potential hazards and secondary production/maintenance process	0.59-1.0	0.43-1.0	43	Satisfactory
Plastic	Potential hazards and secondary production/maintenance process	0.56-1.0	0.35-1.0	35	Satisfactory
Confectionary	Potential hazards and secondary production/maintenance process	0.54-1.0	0.26-1.0	26	Satisfactory

Five (5)-factor productivity improvement remained the best due to provision of wider ranges of improvement opportunity than that of the three (3)-factor productivity measures. Though the minimum possible (%) improvement recorded among the investigated industries was 26, they were all performed satisfactory because the processes eventually attained a maximum productivity improvement ($\geq$1.0) level. In term of widest range of productivity improvement opportunity provision, confectionary processing took a lead (0.26-1.0), followed by tobacco processing (0.32-1.0), while for the shortest range tobacco processing (0.89-1.0) followed by wire and cable (0.65-1.0) were the best under 3-factor model and beverage processing (0.43-1.0) followed by table water (0.42-1.0) remained the best under 5-factor model as shown in Table 6.

Conclusion

The developed productivity improvement model has been effective in bringing agility into the fast moving goods production process by considering the relevant production factors for the purpose of enhancing productivity improvement in process flow availability, quality, performance, waste, and workplace environment. The newly developed 5S-σ tool enabled flexibility in productivity decision making in low-mix high-volume production of fast moving products. The flexible reorganisation opportunity provided by the model has been a solution to the continuous productivity improvement measuring challenge posed by the conventional rigid process flow system.

The findings showed that the manufacturing industry under consideration required some improvements in productivity virtually in all sections, and this study has provided a model solution to this challenge. The newly developed five-factor productivity model has enabled better effective use of production resources in the fast moving goods producing firm than the three-factor model. Generally, the model has made possible timely productivity improvement measure of the process flow to satisfy customers' demands. The following specific conclusions can be drawn from the results obtained from the company used as case study.

i. Productivity measure of the core secondary manufacturing department of the company based on individual factor was satisfactory but overall productivity measure of the combined factors was not satisfactory at all.

ii. Five (5)-factor productivity improvement measure required higher sigma level (six-sigma) than the three (3) factor productivity measure in which three-sigma level was sufficient. High sigma level enabled fast mitigation of huge productivity loss in 5-factor model and hence more effective than the 3-factor model that revealed lower productivity loss.

iii. Five-factor productivity improvement was better than three-factor measure because it provided a wider ranges of improvement opportunity across the case study industries than the three factor model.

Development of intelligent decision support system for the process is a good research area in future. The intelligent system is required to enable robust interaction among the critical productivity factors (availability, performance, quality, waste, and comfort) and production resources (man, machine, material and money) which are responsible for productivity improvement in a process flow.

Acknowledgements

The support given by the Industrial and Production Engineering Research group, and the facilities provided by the Management of the Federal University of Technology, Akure, Nigeria is appreciated. The managements of the fast moving goods production firms are acknowledged for releasing information used in this study..

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