© Universiti Tun Hussein Onn Malaysia Publisher's Office

IJIE

Journal homepage: http://penerbit.uthm.edu.my/ojs/index.php/ijie
ISSN : 2229-838X e-ISSN : 2600-7916

The International Journal of Integrated Engineering

Modelling of Facility Layout Improvement and Breakeven Point Forecast for Plantain Flour Production

Michael Kanisru Adeyeri[1*], Sesan Peter Ayodeji[2], Adebanji Adeleye[3]

[1]Department of Industrial and Production Engineering,
The Federal University of Technology, Akure, 340252, NIGERIA

[2,3]Department of Industrial and Production Engineering,
The Federal University of Technology, Akure, 340252, NIGERIA

*Corresponding Author

DOI: https://doi.org/10.30880/ijie.2021.13.01.001
Received 15 October 2019; Accepted 1 December 2020; Available online 30 January 2021

Abstract: A plantain flour process plant consisting of washing, grating, drying, milling and sieving machines could be set up in a single static layout pattern. But for greater productivity, more efficient use of facility, reduction in processing time and elimination of bottlenecks along the process plant could be obtained. An improved facility layout model was developed for a plantain flour process plant using data from an existing process plant by considering: the breakeven point for investment; and reliability of the facility layout. Comparison was made using data from the initial layout pattern (static layout) with the dynamic layout pattern to aid robust modelling. Considerable level of reduction in the cost of material handling was achieved as congestion along the process plant was minimized and processing time in the dynamic layout generated was much reduced. The breakeven analysis result reflects the extent of improvement per throughput. Testing the models with throughput sizes of 21.87 kg, 43.74 kg, 65.62 kg, 87.49 kg and 109.36 kg, the average processing time to breakeven point was 4703.9 minutes, and this was drastically reduced by 36 % to an average of 3008.5 minutes when the improved facility layout model was introduced.

Keywords: Dynamic facility layout, model equations, material congestion, layout improvement, breakeven point

1. Introduction

Plantain is found in large quantities in some areas of tropical Africa. It is known for its high nutritional content and application in medicine, it is a very perishable food product and needs a well-established and reliable means of preservation [13]. Over the years, plantain has been preserved by conversion of the food to flour, it is dried at a temperature that ensures that the nutritional contents are not destroyed [14]. The application of the product has led to a very high demand for it and effort has been in place to achieve a process plant that ensures the production of the flour in large quantities. Facility layout are designed for better productivity, a facility layout gives better performance when it is dynamic [1, 4]. A process plant for mass production of plantain was designed and an efficient facility layout that eradicates bottlenecks along the production line, brings flexibility into the process flow and as well reduces the cost of production.

A dynamic layout problem is a problem that deals with finding positions of department on the layout for multiple periods such that departments do not overlap and the cost of material handling and rearrangement of layout in-between periods are minimized [2, 5]. Studying dynamic facility layout problems in literatures has shown several different algorithms using well known test problems to assess their performances but real life applications are seems to be ignored. The industries that are prone to seasonal demand changes are expected to study carefully their layouts and possible re-layouts and time horizons [1, 8]. A control system for the operation of the plantain flour process plant was proposed in an effort to improve the quality of the product, increase the speed of production, reduction in process time

**Corresponding author: mkadeyeri@futa.edu.ng*

and removal of human contact with product during production, thereby eradicating the possibility of contamination of product [6-7, 15]. Using break-even point as pivot to industrial production system has proven impactful, efficient and accurate [12]. A breakeven analysis was incorporated into the program design as a way to establish the extent of improvement achieved in a dynamic layout as against the initial static layout. All production cost were categorized into fixed and variable cost [10, 16].

Using the layout improvement models developed by [10], dynamic facility layouts were generated from initial layouts that were largely static, permitting flexibility in throughput size per period over a production planning duration. This work however focuses on management of cost and processing time in plantain flour production process after the implementation of the layout improvement model using breakeven point of investment. Section 2 and 3 discuss the facility layout improvement model and breakeven forecast models respectively. The breakeven analysis and conclusion are discussed in section 4 and section 5.

2. Facility Layout Improvement Model

In the performance evaluation of a plantain flour process plant there are parameters needed for the development of plant layout models [1, 11]. A fractional factor which can be determined from the ratio of the initial material input weight to the expected output weight is very important [10]. This value is dependent on the design capacity of the facilities making up the process plant. It is expected to remain constant regardless of the throughput size processed in the plant at any given time. This factor is an important parameter in the development of layout configuration models. Other parameters include the rate of production of each machine in the process plant, which was useful in the prediction of processing time required for each every process along the plant, number of operators, average wage of the operator per hour, procurement cost, installation cost, cost of 1kg of raw material, cost of 1kg of finished product and machine power requirement. Machine processing time for unit machine was computed using equation (1), while equation (2) estimates the percentage weight relation between the average weight of material before and after processing through a unit machine in the plant.

$$Ti = \frac{WB_i}{R_i} \quad (1)$$

$$WA_i = WB_i * \%Wr \quad (2)$$

Such that: (Wr: $0 \leq \%$ Wr ≤ 1)

Where, Ri is the rate of production of unit machine, WBi is average weight before processing a given throughput, WAi average weight after processing, i is the position of machine in the layout, Ti represents processing time in unit machine, Tt represents the total processing time for a given throughput, Win is the initial input weight.

An objective function that aims at minimizing the total processing time for a given throughput was derived as equation (3), which is the total time required by the processing plant to completely process a given throughput. It is the summation of the processing time of individual machine and time to get the product from one machine to another [15]. The facility layout improvement models developed through parametric relationship between different machines making up the process plant as given in equations (1), (2), and (3), were used to develop flow charts which uses parameters based on data from performance evaluation of an existing plant layout that is largely static and iteratively generate dynamic layout data. In the dynamic layout, delay in process time as a result of congestion of material at some points along the process plant, was removed and efficient utilization of energy and cost effectiveness were ensured. Fig. 1 shows the iteration interface of a facility layout improvement application developed using the layout improvement models. Data for an improve layout that is dynamic over several periods within a planning horizon, ensures efficient utilization of facilities and cost effectiveness were generated using this software.

Table 1 shows the following expected output masses; 21.87kg, 43.74kg, 65.62kg, 87.49kg and 109.36kg [10]. Using these values layout improvement program developed, the time required to totally process a given throughput in a static layout state was computed. The total time taken to process the same throughput size after the layout improvement implementation was also computed. The process time dropped drastically after improvement. For instance, in Table 2 at the throughout size of 43.65kg the total time before improvement was 201minutes, after the layout improvement the time dropped to 62 minutes.

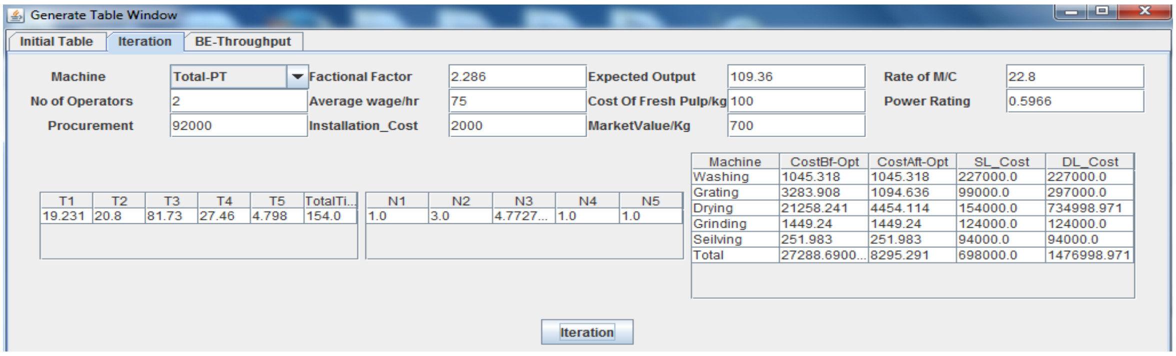

Fig. 1 - Layout improvement iteration result interface

Table 1 - Machine process time before and after the facility layout improvement models implementation

Throughput size (kg)	**Machine Process Time**									
	Washing		**Grating**		**Drying**		**Milling**		**Sieving**	
	T_1	**T_1'**	**T_2**	**T_2'**	**T_3**	**T_3'**	**T_4**	**T_4'**	**T_5**	**T_5'**
21.83	3.85	3.85	12.50	4.2	78.0	16.3	5.5	5.5	0.96	0.96
43.65	7.69	7.69	25.0	8.3	156.0	32.69	10.98	10.98	1.92	1.92
65.62	11.5	11.5	37.5	12.5	234.1	49.0	16.5	16.5	2.88	92.0
87.49	15.38	15.38	50.0	16.7	312.07	65.37	21.97	21.97	3.84	3.84
109.36	19.23	19.23	62.49	20.28	390.07	81.73	27.46	27.46	4.80	4.80

Time taken from the process plant layout commissioning to the breakeven point of investment was computed for the static layout (layout before implementation of models) and the dynamic layout. Analyzing this reveals that the total time required to reach the breakeven point of investment after implementation of the layout improvement model dropped drastically. In Table 2, time taken to reach breakeven point of investment in the static layout was computed as 4668 minutes at the throughput size of 43.65kg, this process time to breakeven point was cut drastically to 3012 minutes after model implementation. This further validates the efficiency of the layout improvement models developed. This model can as well be applied in facility layout that have facilities similar to plantation flour production.

Table 2 - Production costs before and after the facility layout improvement models implementation

	Total Time of Operation (minutes)		Number of Machine Installed		Operation Costs (₦)		Procurement/Installation Costs (₦)	
Throughput (kg)	Before	After	Before	After	Before	After	Before	After
21.83	100.82	30.83	5	10	5457.93	1659.12	698000.0	1476998.97
43.65	201.62	62.00	5	10	10915.82	3318.22	698000.0	1476998.97
65.62	302.45	92.00	5	10	16373.71	4977.33	698000.0	1476998.97
87.49	403.27	123.00	5	10	21831.59	6636.43	698000.0	1476998.97
109.36	504.07	154.00	5	10	27288.69	8295.29	698000.0	1476998.97

Total power rating sums up all power ratings from each machine unit making up the process plant. This helps to determine the cost of energy required per throughput. The throughput size determines the amount of energy required and time of operation of the process plant. The expected output could be a demand size or a fraction of the demand size depending on the capacity of the plant or the size of the product the plant can process per hour.

The time of operation in Table 1 summarizes the process time of all machines making up the layout. The operation time in the layout before improvement was provided for comparison with the layout data generated after the layout improvement. The layout improvement model has a direct implication on the number of machine that needs to be installed. After optimization of the initial layout, the number of machine required for the dynamic layout was generated. The implication of the generated dynamic layout on the machine procurement cost, installation cost and operation cost within a given period is dependent on the throughput size. The various categories of cost implications were recorded before and after the improvement model was implemented on the initial layout.

3. Breakeven Forecast Models

In general terms, breakeven point is calculated as fixed cost of the investment divided by the difference between the unit selling price of product and the variable cost [16]. The fixed cost consists of cost that remains the same regardless of how much is generated from monthly sales. The unit selling price is the price product are sold for, while variable cost includes contingency costs such as transportation and other miscellaneous. Breakeven point in the context of this work is the point at which the cost of material output from the process plant equals the overall cost of investment. When the breakeven points of two different plant layouts are analyzed, it could be a good criterion to measure the efficiency of each layouts. If a layout is improved on, analyzing the breakeven point could also be a good criterion to determine the extent of improvement achieved.

The overall cost investment is a function of machine cost and the cost of operation. The machine cost includes the cost of procurement and installation and could be mathematically represented in equation (4) as

$$MC_i = IC + PC \qquad (4)$$

If the total machine cost for the process plant is taken to be T_{mc}, then the expression for this is as stated in equation (5).

$$T_{mc} = \sum_{i=1}^{n} MC_i N_i \qquad (5)$$

where, MC_i is the cost of a unit machine at position I, Ni is the number of machine at position I, PC is the procurement cost for a unit machine, IC represents the installation cost for a unit machine, T_{mc} is the total cost of machines making up the process plants.

The overall cost, T_c is therefore given in equation (6) as:

$$T_c = T_{me} + O_{CT} \qquad (6)$$

where; O_{CT} represents the cost of operation of the whole plant for a given throughput.

The overall cost of production can also be estimated as a function of the expected output, W_o, the current market value per kg of the product, M_v and the breakeven throughput, $B_{ut,}$ thus giving rise to equation (7).

$$T_c = W_o \times M_v \times B_t \qquad (7)$$

The breakeven throughput is ultimately calculated as stated in equation 8

$$TM_c + O_{CT} = W_o \times M_v \times B_t \qquad (8)$$

4. Breakeven Analysis

A breakeven analysis was incorporated into the layout improvement models developed as a way to establish the extent of improvement achieved in a dynamic layout as against the initial static layout from which it was generated. All production cost were categorized into fixed and variable cost. Equation 9 was derived as analyzed in equation (4) through (7), and applied to determine the breakeven point of investment for the static layout configuration and then for the dynamic layout machine configuration.

$$B_{TC} = \frac{\sum_{i=1}^{n} MC_i N_i + \sum C_{Ti}}{W_o \, x \, \mathrm{M_v}} \qquad (9)$$

where, MC_i is the installation cost; C_{Ti} is the operation cost, W_o is the expected output weight for a specified throughput, M_v is the market value per kg of the finished product, N_i is the number of machine at position i, B_{TC} is the total cost at breakeven point of investment.

The breakeven analysis of a static layout and a dynamic layout generated through the developed layout improvement models was carried out in Table 3. The breakeven analysis validates the efficiency of layouts. It compares the efficiency of the initial static layout with that of the generated dynamic layout, The breakeven results compared showed a wide gap of improvement between the static layouts and the generated dynamic layouts as the time required to reach the breakeven point for a given throughput size was always much lesser in every dynamic layout generated per throughput.

The data generated from the implementation of the layout improvement model was validated using the breakeven point models in equations (4)-(9), the extent of improvement achieved through the layout improvement model was also analyzed using the cost required to reach the breakeven point of investment in a static layout model and in dynamic layout model. Fig. 2 represents the breakeven point interface from the software developed through the layout improvement models.

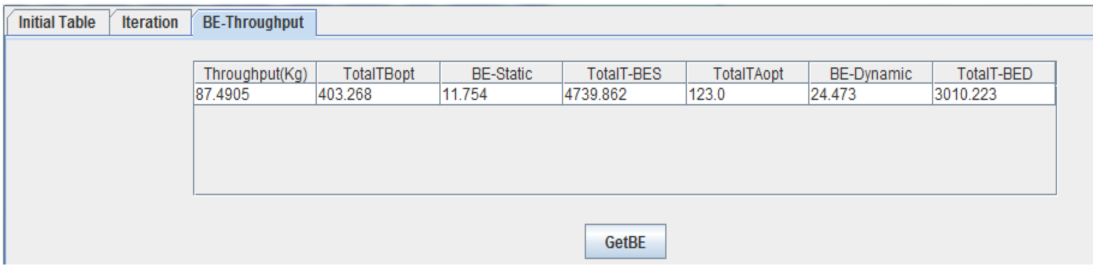

Fig 2 - Break-even throughput results at 109.36 kg throughput size

Table 3 - Breakeven analysis results

Throughput (kg)	**Breakeven cycles (Static)** Before	**Breakeven time(min.) (Static)** Before	**Breakeven cycles (Dynamic)** After	**Breakeven time (min) (Dynamic)** After	**Percentage time reduction** (%)
21.87	45.9	4632.03	96.80	3001.5	35.2
43.74	23.1	4667.98	48.59	3012.6	35.5
65.62	15.5	4703.92	32.51	2992.1	36.4
87.49	11.7	4739.86	24.50	3010.2	36.5
109.36	09.5	4775.80	19.65	3026.2	36.6

5. Conclusion

The layout improvement model developed is helpful in optimizing and upgrading existing facility layouts of any plantain flour process plant or other plants made up of machine similar to plantain flour production machines. All the parameters gathered from the relationships between facilities in the layout were used in the formulation of the improvement model, the performance evaluation of existing plant was also very helpful in the evaluation and validation of the developed model. Using this model, an improved layout that is very flexible across a range of periods within production planning horizon could be generated while efficient utilization of facilities, cost effectiveness, reduced process time and space management were all taken into consideration.

Acknowledgement

The research members of Advanced Manufacturing and Applied Ergonomics Research Group (AMAERG), The Federal University of Technology, Akure, Nigeria were appreciated for their constructive criticism and input towards the successful completion of the research.

References

[1] Berna, U., & Attila, I. (2015). Dynamic facility layout problem in footwear industry. Journal of Manufacturing Systems, 6, 55-61
[2] Alan, R. M., & Artak, H. (2010). Heuristics for the dynamic facility layout problems with unequal-area departments. European Journal of Operation Research, 201, 171-182
[3] Sabastian L. & Alvaro G. (2016). Modular re-design methodology for plant layout. Journal of Engineering Design, 27, 1-3
[4] Yosra, O., Alireza, K., Noordin, M. Y., Nafiseh G. R., & Syed, A. H. S. H. (2015). Production layout optimization for small and medium scale food industry. 12th Global Conference on Sustainable Manufacturing, Procedia CIRP 26, 247 – 251

[5] Desta, A. Hailemariam. (2010). Re-design of layout and material flow of a production plant. A Master Thesis Conducted at the Production Plant of Moxba-Metrex, University of Twerts
[6] Yoshiki K., Joshua A., Danielle S., & Gundayao, Jocelyn A. (2016). Job productivity enhancement through plant facility layout improvement in company XYZ using Promodel simulation. Proceedings of the Asian Pacific Industrial Engineering and Management System, Industrial Engineering Department, Technological Institute of the Philippines
[7] Jordan E., & Matope, S. (2013). Improvement of plant facility layout for better labour utilization. A case study of a confectionary company in Western Cape. SAIIE25 Proceedings, Department of Industrial Engineering, University of Stellenbosch, South Africa
[8] Sara, H., Abdellah, A., & Yahia, E. (2017). A distance reduction approach for simple plant location problem. International Conference on Electrical Information Technology (ICEIT), 55, 1-5
[9] Lifen, Y., Yong, Q., Hongqiang, F., Changxu, J., Xiaopeng, L., & Limin, J. (2014). A reliability model for facility location design under imperfect information. Transportation Research part B, 81, 596-615
[10] Adeleye, T. A. (2017). Design of dynamic facility layout for plantain flour process plant. M. Eng. Thesis (Unpublished). Department of Mechanical Engineering, Federal University of Technology, Nigeria
[11] Sunderesh, S., & Kusiak, A. (1991). Efficiency models for the facility layout problems. European Journal of Operation Research. 53(1), 1-13
[12] Nabil, A., Osama, S. & Ziad, A. (2014). The effect of using break-even point in panning, controlling and decision making in industrial Jordanian Companies. International Journal of Academic in Business and Social Science, 4(5), ISSN 2222-6990
[13] Olutomilola, S. (2016). Design and development of an automated plantain flour processing plant", Ph.D Seminar, Department of Mechanical Engineering, Federal University of Technology, Akure
[14] Islam, M. S., Haque, M. A., & Islam, M. N. (2012). Effects of drying parameters on dehydration of green banana *(musa sepientum)* and its uses in potato *(solanum tuberosum)* chips formulation. A Scientific Journal of Krishi Foundation, the Agriculturists, 10(1), 87 –89
[15] Ayodeji, S. P., Mpofu, K., Oduetse, M., & Olabanji, O. M. (2015). A Control system for a poundo yam flour processing plant. African Journal of Science, Technology, Innovation and Development, 7(3), 192 – 200.
[16] Solution Matrix, (2018). Break-even point analysis, fixed and variable costs. Business Encyclopedia Solution Matrix Limited. ISBN 978-1929500109. Retrieved 2018-06-20