Evaluation of Materials Flow Optimization and Factory Layout in Digital Factories: A Categorical Imperative in Industrial Engineering

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ABSTRACT
The major factor in order to be competitive in present day modern market without incurring additional cost also respecting customer lead time lies on the ability to identify customized products particularly for engineering-to-order companies. The layout optimization is a fundamental issue required in the present day ever-changing environment in the development of a virtual layout in accordance with the Digital Factory concepts; it can be profitable to identify and also to resolve potential problems during planning phase, before its realization stage. The aim of this survey in order to reduce the production lead times is represented by the proposal of a technological solution for the parts feeding system of the industrial plant analyzed and a layout reconfiguration. Phase one provides an overview of the Digital Factory applications, the phase two after data analysis in a Nigerian manufacturing company, Simio simulation software was employed in the design of the simulation model. A comparison of simulations results concerning queue times obtained from different orders and production have been critically done with actual configuration data. The results from the surveyed company indicated an improvement in terms of increase in customer's satisfaction due to total production lead time reduction and reduction of waiting times

Key Words: *Lead time, Optimization, Manufacturing, Simulation model*

INTRODUCTION

There were stability of customers demand in the past compared to this present day activities due to to foreign competition [1]. There has been a tremendous growth in high-mix and customization in modern manufacturing demand [2].

The marketing time has been reduced tremendously; customers now enjoy the previleges of making requests for high quality semi-finished goods at low prices when critically evaluated. This then presents a different scenario of a new world where production factories will now have to work hard and even fight most times to dominate in the competitive market circle.

In the competitiveness of this present evaluation, the employment of various strategies globally to absorb fluctuations in market place in demand, introduction of new products in the production planning by engaging existing facilities are viewed as critical competitive issues [3].

By characterization of flexibility and reconfigurability, all these factors can be said to be responsible for a new trend in manufacturing systems [4].

The imperativeness of the layout is its flexibility. Its very strategic to deciding the the right facility layout for firms. Flexibility has become progressively important in achieving competitive advantage in manufacturing companies [5] hence the decision requires carefully exhibition.

Though complex layout planning design, its activity still involves the optimization of the machines positions, workstations and transportation systems [6]. Recent surveys show that the layout and re-layout optimisation has been modeled to be more efficient by employing information technology tools.

The utilization of simulation techniques in designs and optimisation of existing production processes known to be Digital Factories [7]. Digital Factories are the products development, the production planning and systems. It is now becoming a common practice in production to utilize the digital product development tools in various companies.

Nevertheless, the main focus of this article centres on the production planning of Digital Factories as a concept. Its flexible and allows room for evaluating, designing, monitoring and more so controls the entire manufacturing system employing a 3D simulation with the aim of creating virtual 3D layout which now represent the real facility.

It is essentially useful to development of a virtual layout because it helps to identify and solve potential problems in the planning phase, before the realization of the factory [8].

METHODOLOGY

Survey from Toyota Production System (TPS), with generic Lean Manufacturing principles, which is typically in a manufacturing system, has it that seven types of waste could be identified: Overblown inventory levels, excess production, void running, delays, wasted processes, sub standards and materials handling.

These are as a result of non-functional layout. On the contrary, well-designed layout is responsible for minimizing the material-handling flow, distance traveled by materials and man's movement in relationship with machines within the industry, this makes the manufacturing system super productive valid and efficient. The layout should be designed to reduce or eliminate man machine conflict and encourage flow of materials within the company.

Generally, plant layout is studied to allow the realization of new product and to improve the existing facility to increase production, productivity and reconcile man machine conflicts. It also goes beyond these to ulter the products characteristics, demand by customers, ergonomics of the layout facility. Nevertheless, simulation techniques and modelling enables dynamic analysis which ensure that the plant design problems and potentially generated wastes are seen before the company realizes the plant.

The most employed technique in studying the layout was introduced by Richard Muther in 1973 it's the Systematic Layout Planning (SLP). It is divided into three basic phases:

- Comprehensive and careful data collection,
- Evaluating possible solutions and their performance,
- Selection and improvement of the best solutions.

The method and approach for this survey is schematically shown in Figure 1)

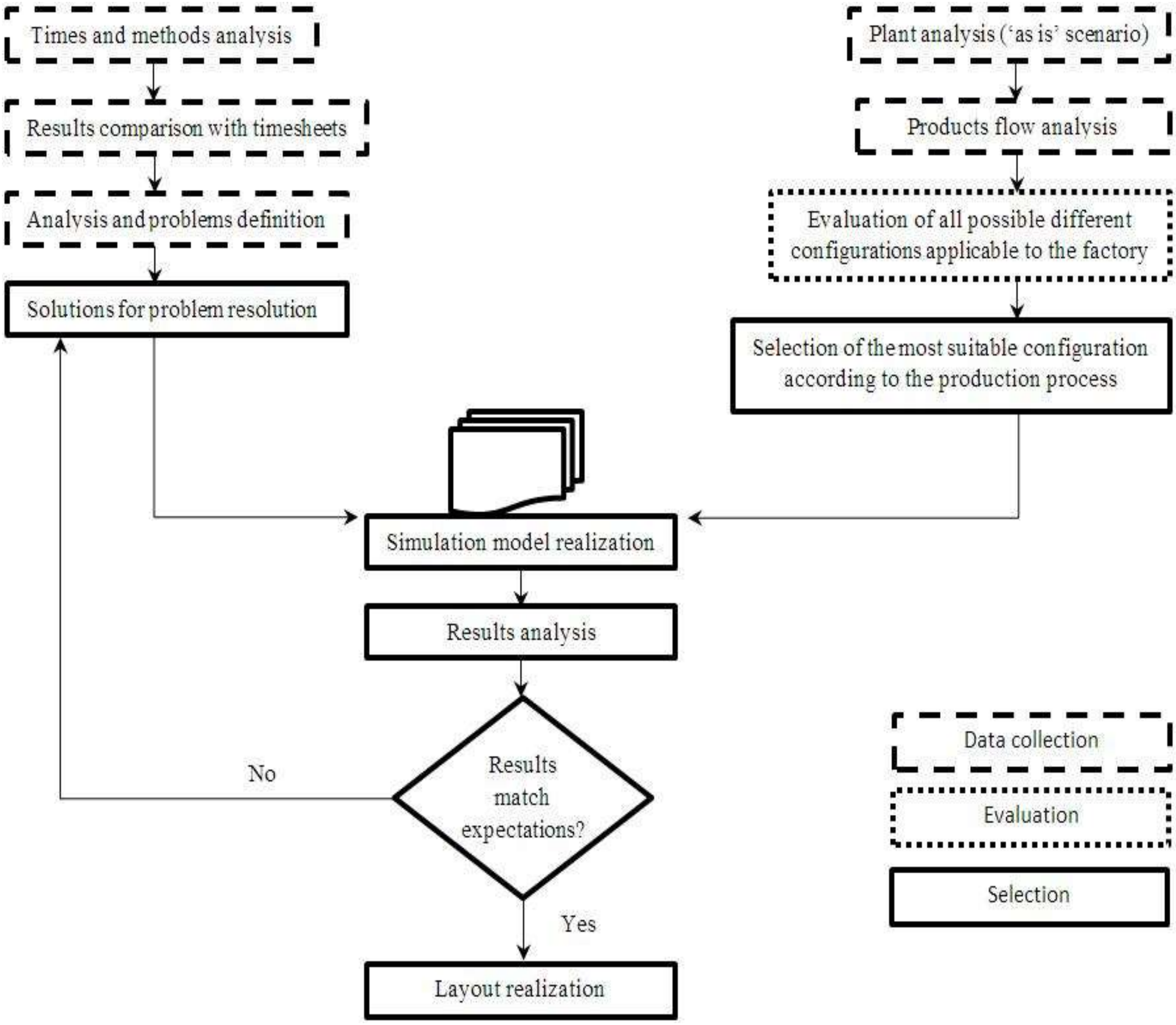


Fig. 1: *Schematic Flow-Chart of the Employed Methodology.*

The analysis of the processing cycle qualitatively (diagram of the operational process) of each of the product has been explicitly represented in Table I.

Table 1: *Product Flow Diagram (Oi: Operations required; Pi: ith Product).*

Pi		P1	P2	P3	P4	P5	P6
Materials Warehouses		▼	▼	▼	▼	▼	▼
Oi	O1	●	●	●	●	●	●
	O2	● ●	● ●	● ●	● ●	● ●	● ●
	O3	● ●	● ●	● ●	● ●	● ●	● ●
Shipping Area		○	○	○	○	○	○

In Table II we have the Hollier algorithm that allows determining the right position of the machinery to make the route as linear as possible.

***Table 2:** Elaboration of from/to Chart (All Data has been Opportunely Weighted and Normalized).*

	TO	1	2	3	∑ From	∑ From / ∑ To
FROM	1	0	0.5	0	0.5	∞
	2	0	0	0.5	0.5	0.5/0.75=0.66
	3	0	0.25	0	0.25	0.25/0.5=0.5
	∑ To	0	0.75	0.5	1.25	

The suitability of this configuration are due to:

- Close distances between workstations,
- Continuity if Flow,
- Flexibility, control and the increased communication,
- Reduction in idle time, maximum queue during processing.

The expected objective to be met is the cost minimization due to materials handling

The 3D model in (Figure 2) is a representation of the planned manufacturing factory that simulates the production process.

***Fig. 2:** 3D-View of the Simulation Model.*

RESULTS

The following are the required data for the comparison of the results of the simulation and the real data: $t_{p,,,,}$ represents the effective processing time required by product *k* for the operation *i* on machine *j*;

- $t_{s,i,}$ time required to set equipment, prepare materials required to perform the operation *i*;
- $t_{q,i,}$ waiting time of WIP before operation *i*.,

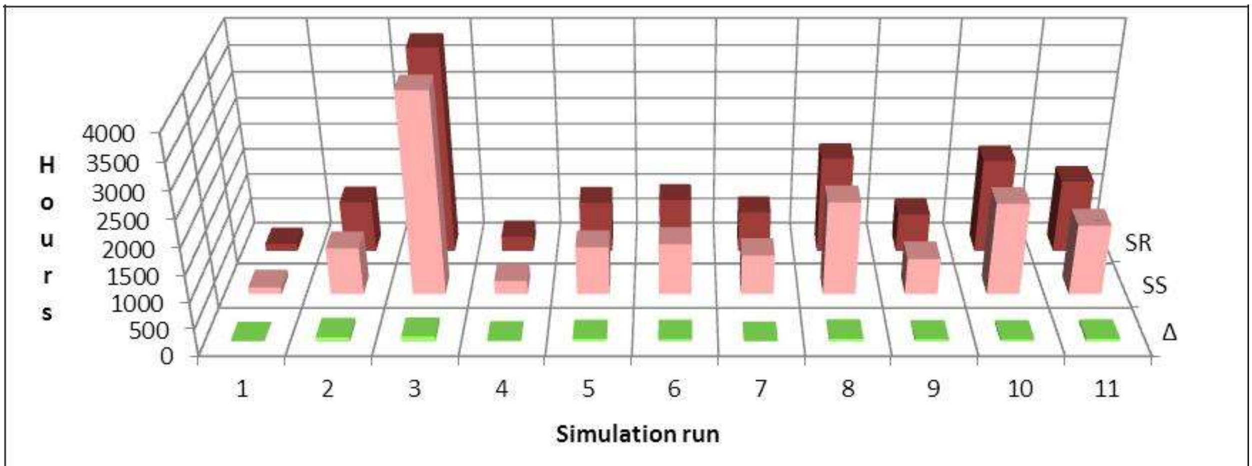
The tables III, IV and V represent a summary of the results obtained by the done simulation. The compared parameterized results with respect to a *k*-factor, are described and discussed below. After inserting and completion of the simulation model of the required data eleven simulation runs start.

Various scenarios have been simulated in accordance with the different company orders and also the obtained results have been compared with real data.

Table III is summary of the cumulative time spent by work in process in each work station and machine while, Table IV gives a reports of comparison between real data and simulation results related to production times. The last column reveals the percentage value due to time reduction (ε_R).

Table V shows comparison of simulated scenario between real. In all the cases, it was observed that the firm obtains a time reduction which ranges from 8 to 1 %.

Finally Figure 3 is a reports of the total time required in 'as is' scenario (S_R), while the total time required in new scenario simulated (Ss) and also the time savings is expressed in hours.



	1	2	3	4	5	6	7	8	9	10	11
Δ	9	81	93	18	51	47	13	54	43	38	53
SS	135	899	3812	267	920	983	767	1783	698	1755	1340
SR	142	980	3904	285	971	1030	780	1837	742	1793	1393

Fig. 3: *The Simulation Results Represented as Total Time Required in 'as is' Scenario (S_R), Total Time Required in New Scenario Simulated (S_S) and Time Savings (in Hours).*

The observation explains that new system performances are definitely better compared to the real ones. Particularly, when the conveyor system was introduced to allows reduction in the waiting time of the batch being completed, time spent by the operators on materials handling between work centres. The time reduction was responsible for results in a substantial total cost reduction for the company.

CONCLUSION

The Digital Factory approach is now known to provide huge support for the decision-making process by completely representating manufacturing process as well as manufacturing layout, it enables the inspection and walk around the (3D model) factory plant.

***Table 3:** The Simulation Outputs Relating to Production Time Spent in Each of the Work Station.*

k/j	1	2	$\sum t_{p,i,j,k}$	1	2	3	4	5	6	7	8	9	10	11	12	$\sum t_{p,2,j,k} + \sum t_{p,3,j,k}$	1	2	3	4	5	6	7	8	$\sum t_{p,4,j,k} + \sum t_{p,5,j,k}$	$\sum t_{p,i,j,k}$
1	641	641	1281	181	155	201	170	118	167	206	187	192	180	-	-	1796	620	611	601	610	634	595	632	601	4045	8021
2	6247	6245	12491	1390	1444	1712	1503	1502	1407	1385	1525	1524	1385	1386	1474	17677	2865	2867	2950	2861	2857	2855	2867	2861	23680	53848
3	7922	7921	15843	7091	7081	6808	6978	7053	6881	6827	6976	6983	6857	6871	6571	83795	16138	16135	16100	16084	16139	16110	16109	16133	128974	228618
4	857	856	1706	168	167	188	143	201	178	154	181	162	169	176	-	1838	1549	1559	1555	1560	1539	1537	1533	1575	12404	15948
5	1333	1332	7168	2080	2079	2078	2078	2080	2080	2078	2079	2081	2078	2078	2080	24988	2879	2878	2879	2878	2879	2878	2878	2879	23027	48087
6	6405	6403	12808	1368	1348	1428	1342	1309	1430	1306	1364	1327	1328	1316	1310	16561	3732	3602	3728	3705	3605	3688	3718	3726	29607	58066
7	1298	1297	2594	633	624	608	614	595	608	646	642	616	658	623	629	7491	4452	4408	4463	4458	4429	4499	4487	4486	35800	45946
8	3132	3132	6264	1770	1757	1828	1798	1771	1757	1813	1708	1814	1787	1792	1751	21394	9892	9923	9890	9898	9884	9891	9924	9928	79241	106899
9	3961	3960	7901	758	773	747	740	769	777	774	748	742	758	748	778	9133	3081	3101	3099	3088	3081	3079	3105	3112	24747	41801
10	4734	4733	9466	3077	3083	3091	3081	3030	3033	3085	3064	3082	3066	3081	3065	36862	7352	7346	7312	7320	7323	7361	7323	7336	58694	105022
11	5344	5344	10688	3723	3728	3711	3738	3736	3758	3683	3705	3707	3738	3746	3686	44672	3157	3096	3134	3095	3088	3081	3125	3111	24893	80253

***Table 4:** The Results as Compared between Total Time (T_R) Required n the 'as is' Scenario S_R and Production Time in the Scenario Simulated S_S in Each Workstation.*

k/i	1			2			3			4			5			$\sum t_{p,i,j,k}$		ε
	T_R	T_S	Δ	T_R	T_S	Δ	T_R	T_S	Δ	T_R	T_S	Δ	T_R	T_S	Δ	T_R	T_S	
1	1291	1280	11	1690	1341	340	1520	1507	13	456	455	1	3575	3437	138	8541	8020	6.10%
2	12616	12491	125	15796	13274	2522	17187	16284	1303	4566	4403	163	8246	7396	850	58811	53848	8.44%
3	16159	15843	316	64397	62888	1509	126017	124523	1494	22452	20905	1547	5229	4451	778	234255	228610	2.41%
4	1740	1706	34	1764	1389	375	9695	9010	685	483	449	34	3425	3394	31	17107	15948	6.78%
5	7119	7105	14	18554	17179	1375	19020	18679	341	8296	7775	521	4767	4348	418	58256	55086	5.44%
6	13032	12808	224	13401	12272	1129	22942	22231	711	4273	4088	184	8128	7457	671	61776	58808	4.75%
7	2622	2596	26	5091	5864	227	3264	3229	355	1925	1887	38	3741	3508	235	4827	4598	1.80%
8	6189	6264	123	17181	19042	1123	7918	7187	1729	5313	5133	186	4245	4054	191	110228	106890	3.02%
9	8040	7921	119	8015	6851	1164	20138	19141	995	2292	2282	10	6018	5908	410	44499	41801	6.06%
10	9748	9566	182	29582	27878	1384	52013	51251	484	9406	9184	222	7335	7142	193	107596	105122	2.27%
11	10859	10688	171	33737	31094	2643	20123	20072	131	13846	13078	271	4662	4620	42	83560	80222	3.87%
$\sum t_{p,i,j,k}$	89815	88268	1347	209471	199672	13800	399508	390478	9030	73888	71059	3139	59610	55611	3999	831714	808390	

Table 5: *The Results Comparison between the Total Time Required in 'as is' Scenario SR and Total Time Required in the Scenario Simulated SS, Obtained Adding the Amount of Time Spent in Queue ($\Delta = T - (\Sigma_i t_{p,i,k} + \Sigma_i t_{q,i,k})$); εT Represents the Total Percentage of Time Saving.*

	S_R	S_S		Δ	Δ	
k	T	$\sum_i t_{p,i,k}$	$\sum_i t_{q,i,k}$	[minutes]	[hours] (rounded)	ε_T
1	8541	8021	55	465	8	6.09 %
2	58811	53848	108	4855	81	8.26 %
3	234255	228610	93	5552	93	2.37 %
4	17107	15949	54	1104	18	6.45 %
5	58256	55087	103	3066	51	5.26 %
6	61775	58856	128	2791	47	4.52 %
7	46827	45946	93	788	13	1.68 %
8	110228	106899	97	3232	54	2.93 %
9	44499	41801	95	2603	43	5.85 %
10	107566	105121	159	2286	38	2.13 %
11	83569	80253	137	3179	53	3.80 %
Σ	**831434**	**800391**	**1122**	**29921**	**499**	

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