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Production System optimization: Case Study of a Local Textile Company

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ABSTRACT : *The manufacturing sector in Botswana has been rapidly growing in recent times. Glam Collections used as a case study organization in this research, is an SME textile manufacturing company with its base of operations in Gaborone, Botswana. The company manufactures a wide range of products in-house and supply to the local market. The company has been growing in terms of scale of production in recent times and this has necessitated it to obtain a larger base of operations which requires an overhauling of their current processes and operations. Hence this research main objective is to demonstrate how Muther's Systematic Layout (SLP) has been effectively used for departmental layout evaluation and facility design. Lean manufacturing tools were employed in the research together with the SLP technique in order to map and analyze the business processes before the systematic layout could be carried out so as to remove waste in the current process flows and standardize the company operations.*

KEYWORDS: *Systematic Layout Planning (SLP), Facility Design, business process mapping, Lean manufacturing.*

I. INTRODUCTION

Lean manufacturing tools and techniques are used in all kinds of production and work environments. It is generally difficult however, to apply lean tools to process manufacturing environments, due to them being characterized by low variety, high volume production which result in inflexible processes [1]. This slow adaptation can be exemplified and justified by the high costs that would be incurred if processing companies were to implement changeover strategies or a reconfiguring of their equipment into production "cells" [2]. It is very difficult for a processing company to shut down a process especially when the setup time for a changeover is long, and it is often impossible or impractical for the company's manufacturing process to be arranged into a flow that could be accommodated by a cellular arrangement.

Billebasch discussed an example of a successful lean implementation story in the textile industry as that of Du Pont's May Plant in Camden, South Carolina. After considering a host of factors that bothered them, the May Plant managers utilized Just-in-Time principles to effectively improve their manufacturing operations [3]. These factors included the poor quality of work-life for the company's supervisors, area managers and operators, as well as constant complaints from customers about the lack of a stringent delivery schedule. Using a "Kanban-like approach", a pull-system was implemented that saw the company's work-in-process and working capital declining by 96% and $2 million respectively. The company's budget declined by $3 million with a measured increase in product quality of 10% [3]. Lean implementation in such an environment as previously stated can be hampered by the high start-up costs involved in shutting down a continuous process facility.

Billesbach *op cit* highlights the issue of implementation as being the continuous nature of the textile process. He states that since most continuous processes culminate in a discrete product or part, it is with these discrete parts and the processes producing them that many lean principles can be applied. "Lean production is the systematic approach to identifying and eliminating waste by continuously improving and flowing the product or service at the pull of the customer in pursuit of perfection" [4, 5].

Drew et al, [6], view the lean system as follows:

- Strict adherence to certain principles to deliver value to the customer while also minimizing all forms of loss
- Each value stream within the operating system must be optimized individually from end to end
- Lean tools and techniques are applied selectively to eliminate the three sources of loss; waste, variability and inflexibility

Lean as an applied concept provides the organization with the opportunity to gain a competitive advantage within the market. The benefits of lean include the ability to identify bottlenecks and areas within the business that require special attention, the chance to save money by reducing process complexity and a means to standardize these processes, thus reducing overall task times for the organization [7].

According to Burton and Boeder [8], the major five principles of lean are as follows;

Principle 1: Accurately specify value from the customer perspective for both product and services
Principle 2: Identify the value stream for products and services and remove non-value adding waste along the value stream

Principle 3: Make the product and services flow without interruption across the value stream
Principle 4: Authorize production of products and services based on the pull by the customer
Principle 5: Strive for perfection by constantly removing layers of waste.

The Lean Production Wastes : David Magee [9] defines waste as existing in 8 different forms. The quality of work, production efficiency and production lead time are all compromised by these different types of waste. The various forms defined by Magee are as follows; over production, over processing, unnecessary movement, unnecessary transport, waiting, excess raw material, defects and unused employee creativity.

Value Stream Mapping : Value Stream Mapping (VSM) is a lean manufacturing technique originally developed by Toyota. VSM is used to identify waste in the value stream for a business or product; once waste is identified, it becomes easier to make a plan to eliminate it. The purpose of VSM is process improvement at the system level. In addition to the information normally found on a process flow diagram, value stream maps show the information flow necessary to plan and meet the customer's normal demands.

Other process information includes cycle times, inventories, changeover times, staffing and modes of transportation. VSMs can be made for the entire business process or part of it depending upon what information is required. Value stream maps come in three types; the Present State Value Stream Map (PSVSM) gives information about the current situation, the Future State Value Stream Map (FSVSM) is obtained by removing wastes from PSVSM and the Ideal State Value Stream Mapping (ISVSM) is obtained by removing all the wastes from the stream. In lean terminology, kaizen activities are used for waste highlighting and reduction. Once the wastes are highlighted, the purpose of a VSM is to communicate the opportunities so they may be prioritized and acted upon. Hence, the prioritization and action must follow the VSM; otherwise it is just a waste like the others [10].

Layout Design : Layout is one of the key decisions that determine the long-run efficiency of operations. Layout has numerous strategic implications because it establishes an organization's competitive priorities in regard to the capacity, processes, flexibility and cost as well as quality of work-life, customer contact and image. An effective layout can help an organization to achieve a strategy that supports differentiation, low cost, or response

[11]. The layout must consider how to achieve the following:

- Higher utilization of space, equipment, and people.
- Improved flow of information, material or people.
- Improved employee morale and safer working conditions.
- Improved customer/client interaction.
- Flexibility (whatever the layout is now, it will need to change when need arises

II. METHODOLOGY :

The research methodology employed in this work was as follows:

- Analysis of the Products and Flow Processes
- Mapping the Material Flow Processes
- Muther's Systematic Layout Planning (SLP) Procedure

Analysis of the Products and Flow Processes : In order to tackle the challenge which was facing the organization efforts were made to first understand the products in terms of which items are being made, the information and material flow, as well as the lead times involved in sourcing the material.

To acquire this information the process owners in plant were interviewed in person to find out the following;

1. Range of products
2. Differentiate the products made inside the company and bought from others
3. Work-in-progress flow from one workstation or department using a "From-To" chart
4. BOM for each product

The "process owners" in question here include the individuals responsible for receiving orders, those responsible for making the actual products, as well as those responsible for creating and sending out material orders to the suppliers.

III. MAPPING THE MATERIAL FLOW PROCESSES

Necessary information on the range of products was acquired from the company. Further the processes mapping was done to achieve the following;

- streamlining the work processes
- exposing the uneconomical/inefficient operations within the flow process
- defining and promoting a deep understanding of the processes

During the process mapping, each product was taken in turn and each process involved in its assembly was observed and mapped out. Later, the process owners, this time the process operators in the production department, were interviewed to gather information for the construction of the Process Maps. The Process Maps took a step-wise format, outlining each step in the assembly of the product in question. The interviewees helped in determining the start and stop points of the flow, with the stop point normally close to the customer. These Process Maps were drawn up alongside the Value Stream Maps (VSMs) for the business. A value stream map for the company was needed to help track the flow of material, information and value itself from the supplier to the end user.

Drawing up the VSM involved defining the value stream and also performing the following;

1. understanding the current state of value stream
2. designing an ideal future state map that will make use of a lean flow for the value
3. creating a work plan for the implementation and execution of the future state map

Value Stream Mapping requires that the flow of material and information between departments be established. The significance of these relations between departments is determined through their activities and how they relate to each other.

IV. SYSTEMATIC LAYOUT PLANNING (SLP) PROCEDURE-ACTIVITY RELATIONSHIP ANALYSIS :

Richard Muther's Simplified Systematic Layout Planning (SLP) procedure was used to develop layout designs for the facility. This layout procedure which was designed and developed in the year 1973 and has proved to be a popular and frequently used layout design procedure [12]. The technique allowed a more general approach to the layout design problem, by allowing for subjective input in indicating the relative importance of the combination for each departmental pairs [13]. The aim of the exercise was to permit the fastest and most convenient means for material flow, whilst ensuring cost reduction as well as material handling reduction. It required the researchers to develop a block layout before any further analysis within each department, such as machine layout, can be performed. Tompkins et. al. [14] explains the activity relationship chart as the foundation of the Systematic Layout Procedure. The From-to-Chart results from an analysis of the material flow and the activity relationship chart results from a study of the relationship between departmental activities and can be done once an understanding has been reached of the roles and relationship between the activities. After this, a relationship diagram can be constructed and then the space relationship diagram will follow. The main outputs of this procedure are shown in Fig 1.

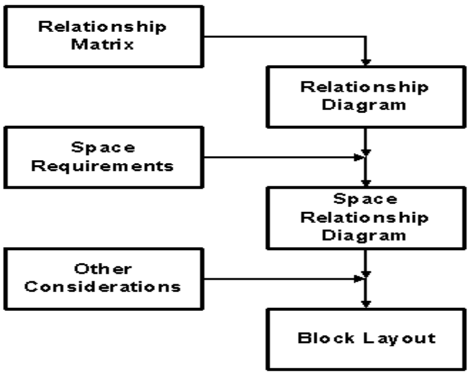

Fig 1. An illustration of the main outputs of the SLP procedure

The "Relationship Diagram" was also used to represent the relationship between pairs of activities by displaying and positioning them spatially, with the relative proximity being the main indicator of the relationship; the closer the blocks are, the stronger the relationship between them is.

V. DEVELOPING BLOCK LAYOUT

After completing the Activity Relationship chart, each department was viewed as an equal sized "rectangle" with its corresponding "AEIOUX relationships" with all the other departments in the facility. The following algorithm was employed;

1. Selected the block "department" with the highest number of "A" relationships
2. Next, selected a block with an A relationship with the first chosen (ties were broken according to which block has the most "Es", then "Is", or fewest "Xs"
3. Next, selected a block with the most highest joint relationship in terms of hierarchy (AEIOUX) with the first two chosen
4. This continued until all departments were chosen

The first block to be chosen was positioned centrally, with the remaining blocks being arranged around it, keeping in mind the order in which they were selected; blocks selected consecutively must be kept close to each other. This rough arrangement gave a general placement for each block, and gave a rough idea of the most optimal block layout. From this analysis, a "Relationship Chart" was constructed for the departments, with a numerical rating, from 1 to 4 given to represent the strength of the relationship between pairs of departments.
Each department was then allocated a floor area in square meters. Considerations on how much floor space was to be allocated to each department included;

- Machine space requirements (obtained from machine manuals)
- Aisle and walk-way requirements
- Proposed material handling system
- Total facility floor space available

The department with the smallest allocated area was taken as the reference block, against which every other department was to be scaled. Every department was sized according to how many divisions of the small reference department can be made, and the rectilinear distance between each department was determined to give a "Distance Chart". The Distance Chart was then combined with the Relationship diagram to create the "Space Relationship Chart", from which a layout analysis was conducted. A score was determined from the chart, with the layout generating the lowest score being deemed as the most effective. To present the layout more accurately, AutoCAD 2016 was used to draft the proposed design. Flow Planner was also used in conjunction with AutoCAD to calculate the distance between departments in terms of aisle length and straight-line distance between each department. Alternative layout designs were also assessed using this software.
Product Clusters : Products being manufactured by the company were assessed according to their processes to determine if it is possible to develop product clusters. These clusters were then proposed for production to accommodate the company's expected growing production capacity to match the expected increase in demand.

The main aim of conducting this analysis was to create clusters to avoid bottlenecks at machines or stations and improve overall productivity of the production floor.

VI. RESULTS AND DISCUSSIONS

Analysis of the Company's Processes

The value stream map of the case study company is shown below in fig 2.

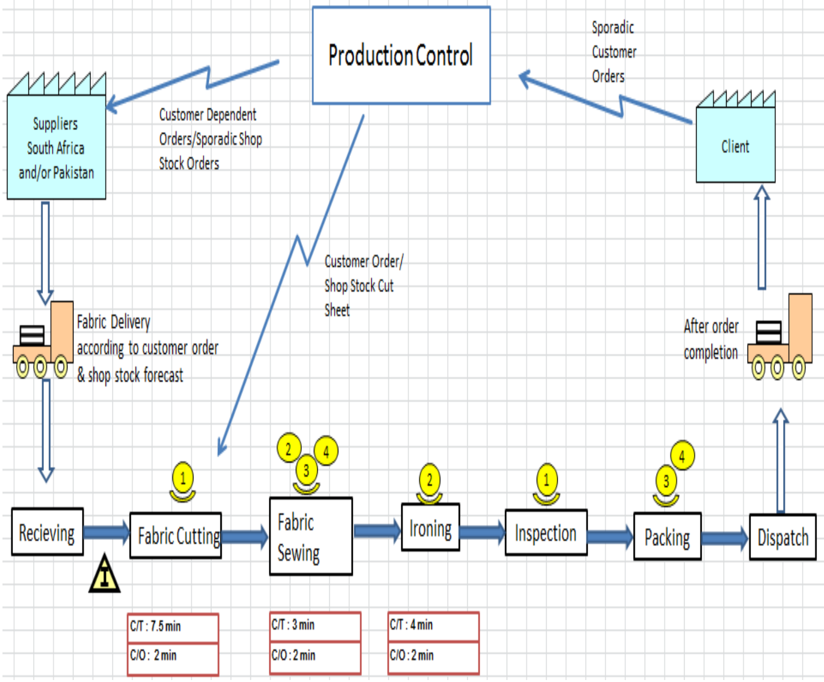

Fig 2 A Value Stream Map of the business

The value addition process began with the placing of orders by Production Control to the company's suppliers as illustrated in fig 2 above. The frequency of these orders was governed by the customers and how often they require products and place orders for them. Production Control also needed material for their shop stock, the inventory for the products on display in the Showroom, and so orders were also sent out to make those items. The frequency of these orders was also random and only done when the stock ran out since customer demand had not been observed to have any patterns that can be observed and tracked. These orders were sent out to the company's suppliers outside the country (South Africa and Pakistan).

The fabric was received on an average of 8 days for orders from South Africa, and an average of 60 days for material orders from Pakistan. Fig. 2 also shows the sections through which the work in progress (WIP) flows. The material was received into production and prepared for processing since orders were most likely waiting to be processed. The fabric was then cut to order and marked out using information from the cut sheet sent to the production floor before being passed on to the sewing section.

The cutting process took an average of 7.5 minutes across all the products according to process operator estimates. The fabric was sent to the sewing section and passed through a specific order in terms of the various sewing machines, depending on the product type and style required by the customer or for the shop stock. The fabric was then taken to the ironing section to be pressed and folded. The time varied according to the size of fabric being pressed but an average of 4 minutes across all products was given by the process owners. After this step, the product was inspected and checked for any stains and loose threads; any soiled fabrics were then washed and passed through the ironing station then once more through inspection. The item was then packaged and held to await dispatch or sent to storage as inventory for the shop. Orders were sent out using the customer's own transportation or a courier sent by the receiving client. The company only made special provisions for orders in quantities above 10 000 units.

The Manufacturing Processes

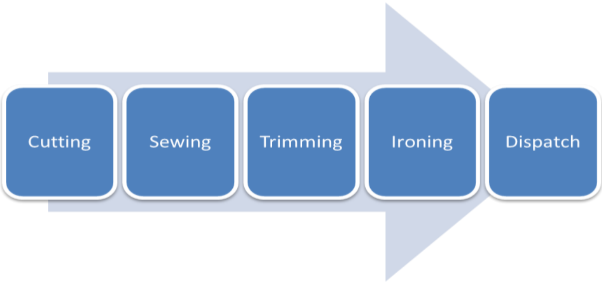

Fig. 3 Manufacturing process

The production flow, as illustrated by Fig 3 was made up of the cutting, sewing, trimming and ironing, and dispatch sections. All of these sections were arranged on the floor in a linear manner to allow for handing over of material and Work-In-Progress from section to section. The manufacturing process consisted of a series of different process steps, which, due to the various products on the company's range, differed from item to item. The pre-production involved in manufacturing involved drawing up of the cut-sheet for a specific customer order, which was then sent to the cutting section of the production floor.

Cutting section : Upon receiving an order, the required type and size of material were entered into a cut-sheet which was then passed on to the production staff. After receiving the cut-sheet, the material required for the order was spread on top of the cutting table, with the order size and quantity ordered being taken into account. Depending on the product being made, a standard length of fabric was then cut from the larger roll of fabric. The processes in the cutting were as follows;

1. Extend/Unroll the fabric
2. Mark the fabric with the length that will be needed
3. Cut the fabric into the required dimension
4. Pass the fabric to the sewing section

Sewing section : This section consisted of six individual machines; three straight sewing machines (for hemming and plain sewing), two overlock machines (for overlocking on fitted sheet edges), and a single embroidery machine (for custom details and zig-zag patterns). Each of these machines carried out a different style and operation of sewing on the fabric, depending on the product being made and the style required. For each of the main five outputs, that was, those manufactured and sold by the company, the flow of operations for the different sections is outlined by Fig 4. These process flows illustrate how one product can go through all the types of sewing machines and how another product only goes through some. The order in which the Work-In-Progress flows from machine to machine also varied from product to product. The sewing section took the cut fabric in its raw form and produced the item in its finished form (save for trimming and ironing). In the current set-up, the sewing operations were aligned in a linear arrangement, with the sewing machines set up against one wall. There were a couple of plastic baskets which acted as the vessels for WIP material flow from one operation to the next. Once one operator was finished with their work, they pushed or dragged the baskets to the next station and operator in the specific sequence for whatever product was being manufactured. Upon completion of all the operations, the final item was checked for any loose threads.

Finishing section : This consisted of two separate tables upon which the garments were steam-ironed and folded to remove any creases in the fabric and have final inspection checks right before packaging. So overall, this section was made up of three major operations, with an extra operation specifically for duvet covers where the press studs were attached to the product. The three major operations are thread cleaning (trimming), ironing and final packing. Upon completion of the sewing operations, the final item was checked for any loose threads, which were trimmed or cut short. Some garments required some washing upon inspection and hence were washed before ironing then final packaging. The operation sequences for each product are shown in Fig 4. Inspection of the garments involved checking for stains and dirt marks on the fabric right before packaging and ensuring that the customer received the order in the best quality possible. The items were then packaged individually and placed in temporary storage to await collection or for inventory purposes.

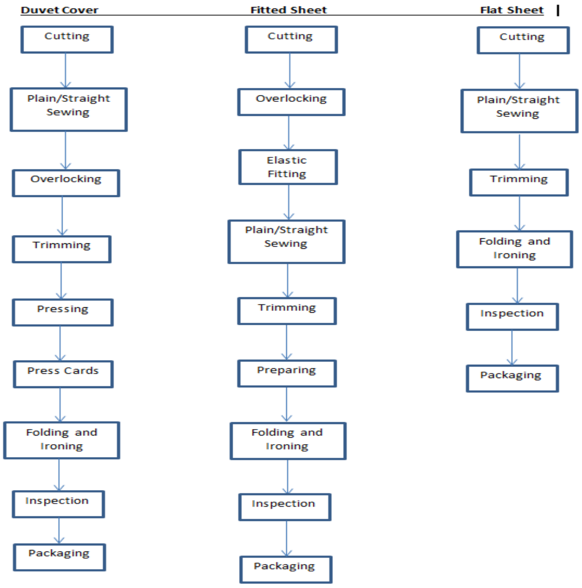

Fig 4 the process steps for Duvet Covers, Fitted Sheets, Flat Sheets

VII. ANALYSIS OF THE EXISTING MANUFACTURING LAYOUT

Fig 5 below shows a schematic of the existing facility, with particular emphasis on the production department. One corner is occupied by the cutting section, the opposite wall by the sewing section, and the adjacent wall is taken up by the finishing section. The fabric is cut in the first section, and then transported to the sewing section. Depending on the product being made and the arrangement of sewing machines being kept at any point in time, the path taken by material from the cutting table and from machine to machine will differ, since each machine is used for a specific type of process. The sewing machines are easy to move around, hence the flexible arrangement, but they generally occupied the illustrated floor space. Each section works on the product and manually hands over the WIP to the next section. If the section is busy, or work needs to be stopped for breaks or even the next day, the work is stored in the plastic bins which are dragged from station to station and section to section. The finishing section retrieves the work from these bins or immediately from sewing by hand carry.

Out of the different types of WIP movement systems applied in garment manufacturing, the most commonly used types are carrying by hand or using trolleys from station to station. The company used both hand and container carriage and storage for their WIP, which suits their scale of production. The variation in the types of products and processes/operations performed on the products also necessitated this movement system, since there's no fixed flow of material between stations. Unlike larger, more advanced factories where the arrangement of machines is fixed and organized, and a slow-motion conveyor can be employed, company's current production layout and processes would deem any automated or mechanized movement system impractical.

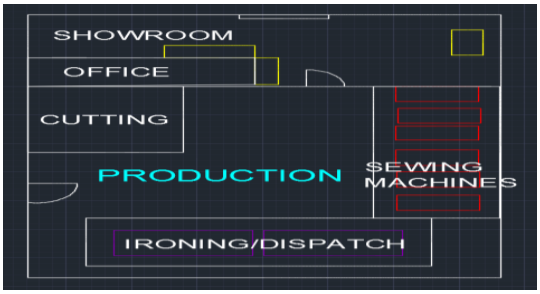

Fig 5 A schematic of the current facility layout

On the downside, unnecessary movement is increased since the flow of material is not fixed from machine to machine. The choice of WIP movement relies heavily on the layout design as well as the technological capacity and expertise of the company and its personnel.

VIII. FACILITY LAYOUT DESIGN

Upon studying the business processes, the information flow as well as the material flow throughout the company, work on the design of the new facility's layout began. The factory shell that the company moved into due to their expansion came with several fixed amenities; a kitchenette, staff changing rooms, showers and ablution facilities. All of these were located on the ground floor and had a significant bearing on the block layout design, given how the production floor should ideally be located close to these facilities to allow short movements to all of them. This would allow for shorter restroom, tea and lunch breaks. The building also had office space already set aside for its occupants on the first floor; an ideal layout according to the researchers would be these offices overlooking the production floor for easy supervision and so this had to be factored in to the design of the floor layout. Given how the factory shell was taken up while completely empty with no demarcations or partitioning, the first course of action was to identify the different sections and departments required by the company and its operations. The Plant Manager and her staff were consulted on this matter but decisions were also made after studying the flow of both information and material through the business. From these consultations and analysis, the following departments were proposed;

1. Showroom
2. Finished Product/ Shop stock storage
3. Raw material storage
4. Production floor
5. Dispatch section
6. Shipping/ Receiving bay

The new facility shell were already provided with fitted offices on an upper level overlooking the factory space and so consideration for office space was unnecessary on the layout design. The ablution facilities and changing rooms were also provided for and had to be neglected, but put into consideration during block layout design (proximity to production floor). Analysis of any layout design involves not only determining the relationships between the activities performed by each department, but also how both material and information flow between each department. When designing the block layout, the following points were taken into consideration;

- Reducing cycle and lead time delays
- Improving product quality
- Reducing aisle congestion
- Reducing wasted floor space
- Improving material and WIP movement and retrieval

To develop alternate designs for consideration and evaluation, Muther's Systematic Layout Planning Procedure was adopted and employed for this analysis. After outlining, developing and understanding of the various roles and relationships between the departmental activities, the procedure outlined in SLP and block layout design were followed.

Activity Relationship Analysis : From the activity relationship analysis in Fig 6, the departments with the most "absolutely necessary" relationships are the two storage sections, the Raw material and Finished product storage (Raw Material Storage – Delivery Bay; Raw Material Storage – Production Floor and Finished Product Storage – Showroom). It is the placement of these two departments that will then have the most control over how the rest of the departments are arranged, since interaction with them is deemed most necessary.

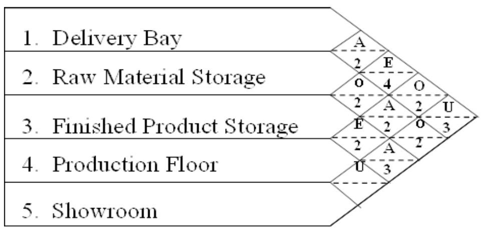

Figure 6 the activity relationship chart

The reasoning for the closeness ratings from Table 1 allocated to each relationship is given using a numerical code explained in Table 2. The justification for giving each rating is represented in numerical code which in turn represents a reason for needing to have departments close to each other, or whether or not the proximity does not matter.

Table 1 The closeness rating value table

Value	**Closeness**
A	Absolutely necessary
E	Especially important
I	Important
O	Ordinary closeness
U	Unimportant
X	Unimportant

Table 2 The key for the reasoning behind the closeness value

Code	**Reason**
1	Same Deck
2	Flow of Material
3	Service
4	Convenience
5	Inventory Control
6	Communication
7	Same Personnel
8	Cleanliness
9	Flow of Parts

The following chart relates the closeness of the departments to the importance of having such a proximal relationship. The numbering used for the table is the same as that used in the activity relationship diagram.

Table 3 Relationship Chart

Department						**Total**
	1	**2**	**3**	**4**	**5**	
1	X	4	3	1	0	**8**
2		X	1	4	1	**6**
3			X	3	4	**7**
4				X	0	**0**
5					X	**0**

From Table 3, a diagrammatic, nodal representation of the relationships, illustrating the "strengths" of the interdepartmental relationships were drawn up, using lines to join the nodes (Fig 7). Based on this Nodal diagram the space relationship diagrams in Figures 8 and 9 were later on constructed.

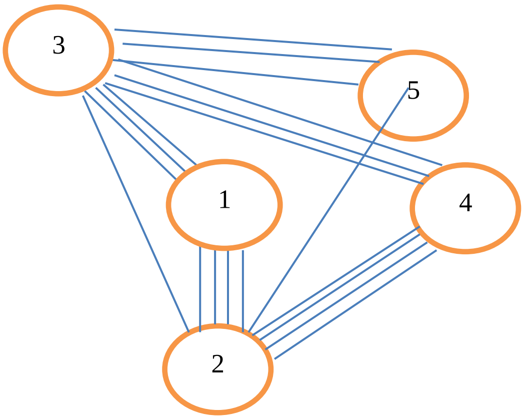

Fig 7 Nodal Representation of Departments

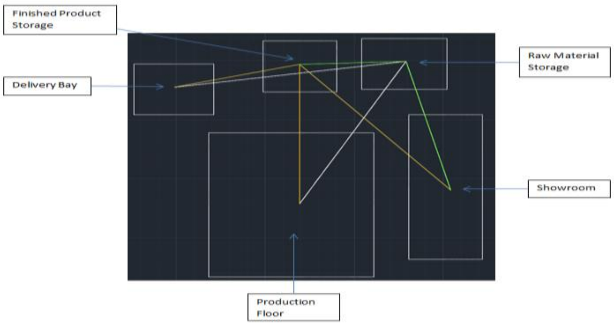

Fig 8 Space Relationship diagram for the new facility

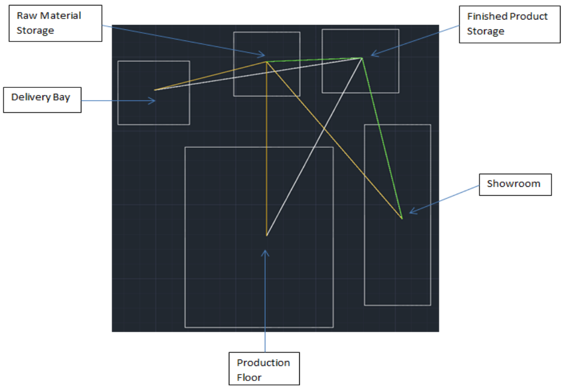

Fig 9 Alternative Space Relationship diagram with the finished product and raw material storage swapping locations

The key for the Nodal Representation of Departments diagram, is such that the interdepartmental relationships denoted by the lines as below;

- Four Lines – Very Important
- Three Lines – Important
- Two Lines – Useful
- One Line – Not Very Useful

Departmental Floor Allocation : Upon consultation with the company owner, measurements of the floor area were taken with each proposed department in mind. Going into this exercise, the only prerequisites with regards to departmental floor space were that the two storage areas (finished product and raw material) could be roughly the same size, and that the production area would need to take up most of the available floor area. As much as the layout and design of each individual department were integral to the design of the facility as a whole, the layout of the storage areas were focused on first. The design of the storage area plays a very important role in the running of the facility since its main function is to store the company's products. The storage sections could only be designed to hold shelving as high enough for the storekeeper to reach without difficulty since the organization still used the picker-to-part material handling system. Shelf height as high as the ceiling is could be used later to accommodate for expansions if necessary. For the finished product section, the proposed shelving dimensions were 1.2 m by 0.61 m for the various items coming in from production. Standard-sized shelving was used as is more appropriate and more cost effective compared to individualized sizing and was designed to accommodate the various products that come in various sizes and packaging. The suggested layout which could accommodate approximately 12 of these shelves is shown in Figure 10.

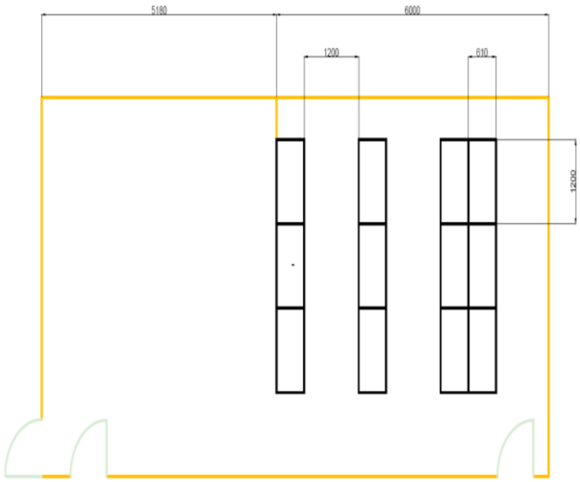

Fig 10 Recommended layout for the Finished Product storage section

The shelves selected for use were measured against the duvet cover packaging which was the product which took up the most shelving space, measuring 560 x 320 x 460 mm. The standard walkway width was designed to be 1.20 m which was deemed sufficient enough for the manual material handling system used by the organization.
Taking into consideration that the company did not produce a lot to stock, the storage areas had to take note of that. Hence the chosen floor space allocations were 6 m by 5.40 m for finished products and 5.18 m by 5.40 m for raw material. Decision was also taken to divide the two areas by tape so they can be easily adjustable if need be. Another consideration for the organization was to have an area designated to a bonded warehouse. Hence a separate restricted movement area had to be included in the final layout adjacent to the raw material storage area.

Another space allocation went to the showroom area, which currently holds 7 separate shelves 610 mm wide, aligned along the proposed showroom/production area partitioning as shown in Fig 8. These shelves were expected to be used as shelving for sample products and general display for the showroom, which can be seen in Figure 11. The current layout and partitioning of the shelves was not expected to change in the near future, and so was taken into consideration during floor area allocation for the showroom. This department also carried two beds measuring 1850 by 1500 mm positioned as shown in Figure 11, as well as a meeting table. Combined with several mannequins and a desk with a computer and its wiring, and a couch for customers at the front of the room, all of these measurements and space requirements were taken into account when allocating floor space to the showroom. The company owner also expressed a desire to include a "Glam Baby" section towards the back of the room, that will be dedicated to displaying a range of products tailored for babies and toddlers, and will be catered for in the space allocation since the aforementioned components already took up only a little over half of the space allocated to the showroom.

Figure 11 A snapshot of the Showroom area

Unlike the showroom, which was unlikely to have its layout changed drastically, the current production area had six sewing machines that were mobile enough to be maneuvered around, as well as the cutting table (3.68 m by 2.76 m), currently positioned in the center of the room. The expected change in the operations of the business due to production volume increases were expected to put demand for more production area due to the possible increase in machine space requirements. Hence this needed to be taken into consideration in the production space allocation in the new facility. The process operators used sewing machines mounted on tables 1.20 m by 0.53 m, with no stated space requirements, such as for ventilation of the machines. The only space specification that was used was the need for free movement between the sewing tables such that an operator working at one station is not disturbed by another moving past that station. But at the same time the tables needed to be close enough to allow for work-in-progress to be passed along to the next table without too much movement. This led to a decision to use a space of 1 m around their periphery; meaning that a block of floor space 30.2 m2, given the mobility of the tables (5.59 m by 5.40 m), was set aside for the sewing tables alone and must be accounted for in the total production floor space allotment. The above-mentioned dimensions and space considerations are illustrated in Fig 12.

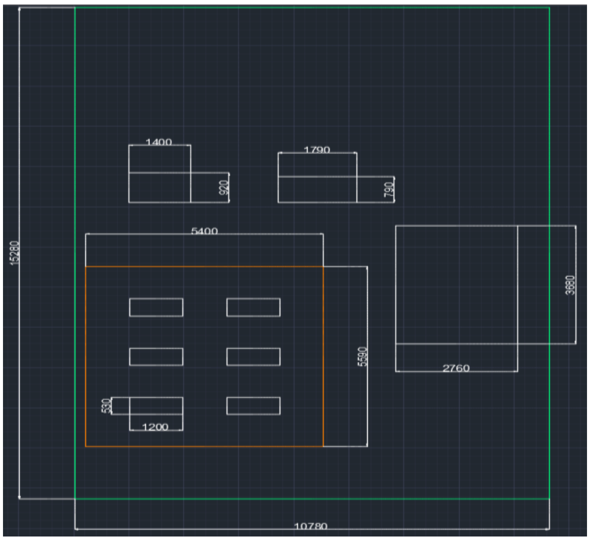

Fig 12 Recommended positioning of the components of the Production Area

Besides the cutting and sewing tables, the production space also held a relatively small dispatch table (1.79 m by 0.79 m) and a pressing table (1.40 m by 0.92 m), which regardless of their smaller and seemingly insignificant relative size, had to be considered with regards to space allocation. Poor layout design is often the root cause of the lean wastes as previously discussed, hence a well thought-out design was a necessary requirement as the organization looked to expand. Figures 13 and 14 represent a layout developed with a reduction of employee movement and interdepartmental communication improvement in mind; from the positioning of the departments relative to each other, to the floor area allocated to each. The most optimal solution was obtained after analyzing the minimum distance travelled from both Flow Planner and AutoCAD 2016.

Fig 13 Suggested final layout and arrangement of the partitioning on the ground floor

The main aim of the layout design procedure was to have smooth and directed flow of material and workers from one department to the next. Hence using Muthers' Systematic Layout Planning (SLP) technique, the proposed relationship diagram can give confidence that a technical thought has been put in designing the organizational layout. In the new layout, the raw material, i.e. the fabric used in production is expected to be received from the Delivery Bay (F). The material will then be taken in to the Raw Material Storage (E) as inventory, where the workers on the production floor will then retrieve rolls of whatever fabric they require and also return whatever fabric remains. This all serves as justification for having the Delivery Bay and Raw Material Storage positioned directly next to each other, to minimize movement of both material and labour.

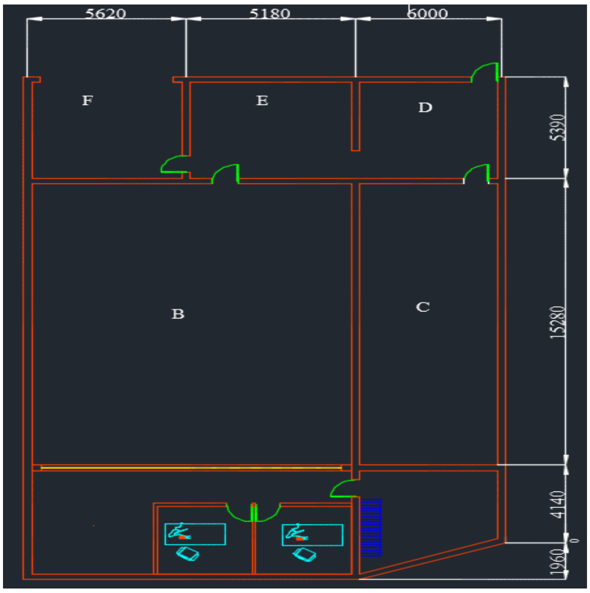

Fig 14 First floor plan view, office space included

Finished items from production are sent from the Production Floor (B) to the Finished product/shop stock storage section (D). From here, inventory for the items on display in the Showroom (C) are kept and retrieved as retail stock; when customers walk in and request a particular item on display (garments, amenities), the front desk personnel retrieve the item from this storage through direct access from the showroom. Section "A" from

Fig 13 represents the passage running underneath the balcony overlooking the production space and was left to the owner's discretion as to whether the passage is closed off from the production floor or not. Hotel orders, those requiring immediate dispatch, will be held in the section of the production space set aside for inspection and dispatch. Instead of having its own separate division or department, dispatch will be given a small section of the production floor close to the entryway leading to the storage sections. This enables separation of the inspection, packaging and dispatch operations from the rest of the production operations and also reduces movement by optimizing access to finished product storage.

Walkways and Emergency Exits : When allocating floor space to the various departments, a minimum of 1.20 m was provided as walkway space to allow for easy movement of workers across the floor. This was done with accordance to the Building Control: Subsidiary Legislation, which details Building Control Regulations. The walkway space chosen was for 0 – 50 persons within the facility, and even though the table indicates that 0.90 m be used as the standard width, an allowance of 33% was made and 1.20 m was proposed to be used as the standard width of walkways through the storage sections.

The production floor currently provided for a lot more space for movement, given how few machines there were, but the more limited space designated to the storage sections means that only 1.2 m was provided between the shelves for maneuvering. A width of 1.90 m (with an added 60 % of the standard 1.20 m as allowance) is given to the passage running in front of the storage sections to provide for easy maneuvering of the material handling equipment such as trolleys from storage to production or to and from the loading/shipping bay. With the emergency exit positioned at the finished product storage area, the space there will need to accommodate easy and uninhibited access to the exit door in cases of emergency. A width of 1.20 m was once again provided as space for the walkway leading towards this exit. Demarcations needed to be made on the floor to indicate that no objects are to be placed on the passageway leading to this exit.

Process Flow System Review : The production levels that the company currently operated at made the prospect of a production layout such as cellular manufacturing impractical. The company's main products could be grouped into families based on similar manufacturing operations and grouped into cells. However, given the limitations presented by the current low production and small number of machinery, the machine cells would not be used effectively, but also, not enough machines would be available for each cell. The process steps for the products would also need to be reviewed to help identify any step that can be eliminated or any steps that could be combined to shorten the overall processing times. Having undertaken the facility layout design exercise with future expansion in mind, group technology analysis was carried out regardless, in anticipation and preparation for future increase in demand and production. Assuming that operational processes remained the same as time progressed, the Direct Clustering Algorithm (DCA) method developed by Chan and Milner (1982) could be used as in Tables 4 to 6 to create operational "clusters";

Table 4 Process Allocation

Step 1 **Operation**

		Cutting	Plain Sewing	Over locking	Elastic Fitting	
Product	Duvet Cover	1	1	1		3
	Fitted Sheet	1	1	1	1	4
	Flat Sheet	1	1			2
	Pillow Case	1	1	1		3
	Base Cover	1	1	1	1	4
		5	5	4	2	

Table 5 Column and Row Ordering

Step 2		Operation				
		Cutting	**Plain Sewing**	**Over locking**	**Elastic Fitting**	
Product	**Fitted Sheet**	**1**	**1**	**1**	**1**	**4**
	Base Cover	**1**	**1**	**1**	**1**	**4**
	Duvet Cover	**1**	**1**	**1**		**3**
	Pillow Case	**1**	**1**	**1**		**3**
	Flat Sheet	**1**	**1**			**2**
		5	**5**	**4**	**2**	

Table 6 Product Clustering

Step 3		Operation				
		Elastic Fitting	**Overlocking**	**Plain Sewing**	**Cutting**	
Product	**Fitted Sheet**	**1**	**1**	**1**	**1**	**4**
	Base Cover	**1**	**1**	**1**	**1**	**4**
	Duvet Cover		**1**	**1**	**1**	**3**
	Pillow Case		**1**	**1**	**1**	**3**
	Flat Sheet			**1**	**1**	**2**
		2	**4**	**5**	**5**	

For the analysis above, only the cutting, elastic fitting and sewing operations (plain sewing and overlocking) were considered; trimming, inspection and packaging were common to all the products and were therefore neglected only for the clustering exercise. The proposed cells would be made up of only the machinery required by the products being made in each cell. Cell 1 will be responsible for producing fitted sheets and base covers, since they both require processing from the same machinery. Cell 2 will be responsible for duvet covers, pillow cases and flat sheets, also because their process step are more or less similar.

Creating cells dedicated to groups of products will help reduce bottlenecking of machines along the production line, which would otherwise be expected when a single production line is used for batches of products of varying types. Therefore, to prevent bottlenecks in production once operations and demand increase by a substantial amount, it is recommended that the two clusters outlined above be used to form cells such that processing for each part within a cluster occurs in a single cell. After reviewing it is recommended to merge the Ironing and Inspection processes into a single operation.

The process operator responsible for Ironing and Folding could also be given the responsibility for inspecting the product as they iron and fold it. This means that the item can then be passed directly on to packaging, skipping the individualized inspection process step and possibly reducing total processing time for each item. Figure 15 below shows the proposed process steps with the individual Inspection step combined with Ironing and Folding.

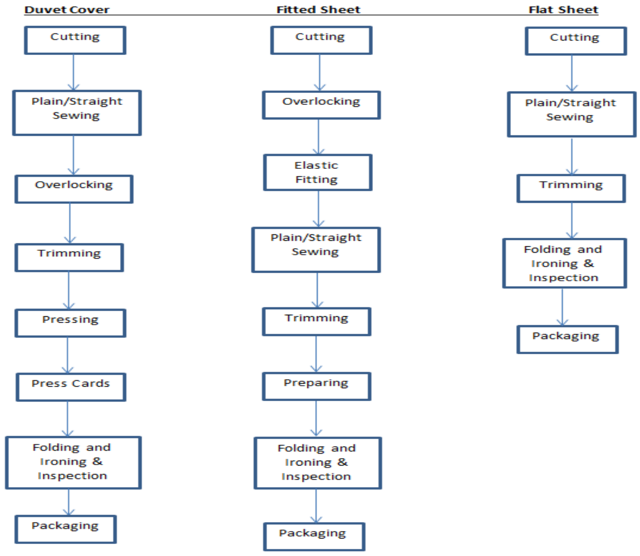

Fig15 proposed process steps

IX . CONCLUSIONS

Opportunities for business improvement were identified after a detailed analysis of the company's processes through mapping of its information and material flow. The flow of value from the supplier, through the business and to the customer was documented, mapped and illustrated in this work. The various sections of the production floor; the cutting, sewing and finishing sections were also analyzed, with the steps taken by the products through each as value is added being mapped and illustrated afterwards. To create a base for process improvement, as well as facility layout design, the current system (production and storage) being used by the company was placed under scrutiny, to identify points of weakness that would serve as starting points for overall business improvement. The movement of fabric from one point to the next was described and the type of material handling was identified as hand carry, which worked well for the small production quantities and floor area being used in the facility for production

Facility layout design for the new facility then began with an analysis of the inter-departmental relationships that culminated in an Activity Relationship diagram, a From-to-Chart (Relationship Chart) and a nodal representation of the strength of the relationships between the departments. All of this served as the basis for the development of a Space Relationship diagram and the space constraints were taken into consideration, along with the proposed walkway width of 1.20 m for the new facility. The process steps were revised and altered for process time improvement and were recommended for the final implementation of the production system once the layout had been designed and implemented. Finally, inventory control was tackled with the redesign of the company's cut and dispatch sheets that will help improve accountability in terms of material consumption and movement of Work-in-Progress between stations and/or

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