INDUSTRIAL BUILDINGS DESIGN GUIDELINE BETWEEN SUSTAINABILITY PRINCIPLES AND LEAN MANUFACTURE

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Abstract- Egypt is one of the countries which faces great challenges in industrial investment due to land expensive prices, also its products have no ability to compete in the international markets. Furthermore, The Architectural design process of industrial buildings has no impact on Factory productivity and also its products' prices. So the purpose of this research was to define the Architectural design guidelines for the industrial buildings and study how it can achieve the principles of lean manufacturing and sustainability complementing with each other, considering these following effective factors; environmental, aesthetical, functional, economical, building operation and industrial production. These criteria have been applied in a hygienic factory (AFF) -located in Borg Al Arab, Egypt- by studying the existing building and making a renovated design taking into considerations the previous factors so that the principles of lean and sustainability could be achieved. After the execution of the renovated phase, Annual measurements have been recorded to study the rate of productivity and energy consumption, the number of workers and employees and also the relations between them in order to study their feasibility by applying lean principles through the architectural design guidelines. Moreover, an annual study of sustainability principles has been carried out considering the following factors; noise, thermal isolation, illumination, materials and power consumption. Consequently, it has been found out that The Architectural design process contributes in achieving lean and sustainability principles by a various rates.

Keywords- Cellular Manufacturing, Design Process, Guidelines, Industrial Buildings, Lean Manufacturing, Reducing Waste, Six Sigma, Sustainability, Zero Wastes.

I. INTRODUCTION

The world has become aware of the close link between the environment and the economic development. But with the exploitation of the natural resources and the production of pollutants in addition to the production of dangerous wastes, it causes a tremendous pressure on the environment. From this point, the sustainable development is defined as

"satisfy the needs of the present generations without compromising the needs of the future generations."
Also, most of the world at the end of the last century started to pay their attention to sustainable development and environmental protection. On the other hand, industrial buildings are considered as the most polluting and non-sustainable buildings.
So industrial building design guidelines and methodologies were studied and created for the designers to achieve the principles of sustainability, including; optimum usage of energy, zero waste and no pollution affecting the surrounding environment.
In the other hand, Lean manufacturing is a leading manufacturing paradigm which has been applied in many sectors of the world economy in order to improve product quality, reduce production costs, and to be "first to market" in addition to the quick response to the customer needs. Lean principles is ***"producing what is needed, when it is needed, with a minimum amount of materials, equipment, labor and space."***
So in this research, the relationship between lean manufacturing and sustainability principles has been studied in addition to how a design guideline and an evaluation checklist can be created for the industrial buildings.

II. INDUSTRIAL BUILDING DESIGN GUIDELINES

Industrial building design has to regard the following factors:

- The Environmental factor: in which sustainability, Thermal comfort, noise and healthy environment for the users are considered. Also, natural ventilation has to be regarded to prevent pollution, whereas buildings openings shall take prevailing wind direction into account. Moreover, reducing potable water consumption and ensuring acoustic treatments should be considered. So that, the building is designed to be integrated with surrounding context.
- The Aesthetical factor: which considers unity, historical dimension of the surrounding area, and exterior facades' design of the building in a functional framework. Furthermore, it respects city regulations, users' comfort without losing its innovation, creativity and flexibility of the design.
- The Functional factor: in which flexibility of the design is expected to provide a sufficient area to meet current and future needs, in addition to products' changes, vertical and horizontal expansion possibilities as well as minimizing the visual impact of loading bays and service areas. Also, the building should be easily accessed and the relationship between spaces must be based on the operations' sequence so that circulation types has to be separated in order to avoid flow interference.

- The industrial Production Factor: in which the integration of site planning, main internal movement and the outer site road networks is considered to achieve the best way of supplying the factory with raw materials. Additionally, Production exits and employees' in/out circulation, the product's flow products' quality control has to be regarded to achieve the best standards. Also, Periodical maintenance of the machines and has to be done.
- Building operation factor: in which safety of the building and the users is considered. Buildings have to follow the firefighting criteria which are mentioned within the industrial safety & security requirements as; providing fire detection devices and automatic fire extinguishing systems. Also, potable water reservoirs are not to be located near the sanitary & industrial drainage reservoirs so that water is not mixed. Furthermore, Drainage reservoirs are to be lined with insulators to make sure they don't pass the walls and reach potable water or the subsoil, conditions of water drainage and primary treatment are to be fulfilled before draining to the central treatment. The criteria and the conditions of untreated sanitary drainage to the local network, according to the executive regulations of the environmental system have to be taken into consideration.
- The Economical Factor: in which activities are planned and conducted with particular attention to reduce sources and lower consumption of materials as well as wastes recovery. The relative large impact of productivity and health gains reflects the fact that the direct and indirect cost of employees is far larger than the cost of construction/energy that act as the benefits of the green buildings; including cost savings (from reduced energy, water, and wastes). Therefore, in order to lower operations and maintenance costs, the optimum case of occupants' circulation and production flow have to be obtained to reduce the occupied land.

III. SUSTAINABILITY

It is a pattern of resources use which aims to meet human needs while preserving the environment, so that these needs can be met not only in the present, but also for future generations. "It is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

3.1 sustainable Development Elements

Each point of view corresponds to a domain that has its own distinct driving forces and objectives.

- The Economy domain is geared mainly towards improving human welfare, primarily through increases in the consumption of goods and services.
- The Environmental domain focuses on the protection of the integrity and resilience of ecological systems.
- The Social domain emphasizes the enrichment of human relationships and achievement of individual and group aspirations.

3.2 Sustainable Objectives In Architecture

As the society's economic status improves, its demand for architectural resources will increase (ex: lands, buildings, products, energy, and other resources). This in return increases the combined impact of architecture on the global ecosystem, which is made up of inorganic elements, living organisms, and humans. So that architecture is considered one of the most conspicuous forms of economic activity.

The three objectives of Architectural Environmental Education:

- Creating environmental awareness.
- Explaining the building ecosystem.
- Teaching how to design sustainable buildings.

3.3 Sustainable Architecture Principles

Three principles of sustainability in architecture are proposed. These principles can provide a broad awareness of the environmental impact of the architectural consumption.

- Economy of resources: By economizing resources, architects reduce the use of nonrenewable resources in construction and operation of the buildings. There is always a continuous flow of resources, natural and manufactured, in and out of a building. These flow begins with the production of building materials and continues throughout the building's life span to create an environment for sustaining human well-being. Additionally, there are three strategies for the economy of resources principle which are energy conservation, water conservation, and material conservation. Each focuses on a particular resource necessary for building construction and operation.
- Life design cycle: Elements of the building are selected on basis of life-cycle costs which consist of three phases; Pre-Building phase: Using materials that are made of renewable resources, extracted without ecological damage, recycled, recyclable, long-lasting and low maintenance in order to minimize energy needed to distribute materials. Building phase: Scheduling construction to minimize site impact, provide waste separation facilities, use nontoxic materials to protect construction workers as well as end users and specify regular maintenance with nontoxic cleaners. Post-Building phase: Adapt existing structures to new users and programs, re-use and recycle of building's components and materials, and also re-use of the existing infrastructure.
- Humane design principles embody three strategies which improve the quality of life for humans and other species; Preservation of physical conditions: Understand the impact of design on nature, Respect topographical contours, do not disturb the water table and Preserve existing flora and fauna.

Urban Design& Site planning: Avoid pollution contribution, promote mixed-use development, create pedestrian pockets, provide for human-powered transportation and integrate design with public transportation. Design for human comfort: Provide thermal, visual and acoustic comfort, provide visual connection to the exterior, provide operable windows, provide clean and fresh air, accommodate persons with differing physical abilities and use nontoxic, non-outgassing materials.

IV. LEAN MANUFACTURING

Lean manufacturing is a manufacturing philosophy which focuses on delivering high quality products at the lowest prices and at the right time. Lean manufacturing focuses on eliminating waste or non-value added activities. As well as its basic value proposition is that principles for improving workflow, decreasing setup time, eliminating wastes, and conducting preventive maintenance which will speed up business processes and return quick financial gains.

New Lean Definition: "Develop the highest quality products, at the lowest cost, with the shortest lead time by systematically and continuously eliminating waste, while respecting people and the environment."

4.1 aims Of Lean

- Small batches: The aim is to make only one item at a time at each stage of manufacture, rather than each process being completed on multiple items before the whole batch is handed on to the next process, so that it can be used as part of the inventory reduction strategy, also it helps to maintain a steady flow of work through the plant and to avoid wasted time.
- Waste reduction: Waste can be defined as "anything the customer doesn't pay you to do", but there are some "wasteful" activities that are actually essential to the business; as time spent changing over tools between processes, measuring and testing products for quality control purposes, or administrative work to process orders. Consequently, those wastes should be minimized but not to be eliminated.
- Product families: In Lean manufacturing, the ideal is to organize everything by product families. So wherever possible, all the equipment required to make each family of products will be grouped together. Therefore, work flow through processes and transportation within the factory are reduced.
- Ultimate value: value is defined as the opposite of waste. When you are not adding value, you are creating waste. That's why lean encourages companies to maximize the percentage of their time that is spent adding value.
- Value stream mapping: Lean encourages the consideration of the value stream of products in which it maps all the steps in this value stream against time; as extraction of raw materials, processing, transporting, forming, assembling, waiting and storage. As well as helping companies to understand the value stream in order to estimate the percentage of the time which adds value to the customer and work out where wastes are occurring.
- Inventory reduction: Inventory generally acts as a "buffer" between processes or between the company and its customers or suppliers against delays. However, excessive inventory takes up room, can become obsolete, may have to be reworked to provide exactly what the customer requires, takes time and effort to put into storage, ties up money and can hide problems in processes. So it is not surprising that inventory reduction is another of Lean's main features.
- Just in time: This obvious idea is actually a rather radical shift from mass production if rigorously applied, as it means that they are not only bought-in parts and materials to be supplied in smaller, more frequent deliveries, but also within the factory work is undertaken in much smaller batches so that processes feed components to the next process, and ultimately products are made "just in time" to complete orders for customers.
- Pull "what is needed to supply orders": Pull manufacturing means making only what is needed to supply orders which are received. In a "pull" system, each operation will only produce parts when the succeeding operation indicates that it requires them and in quantities that are required. However, the "buffer" of inventory between processes will be minimal and tightly controlled. Additionally, Lean tools include ways to control the buffer and to pass on the order to start producing parts.

In contrast, typical mass-production manufacturing relies heavily on forecasts of sales, which are used to create manufacturing schedules that decide what each process will make and when, to build a finished goods inventory from which orders are fulfilled.

- Single minute exchange of dies (SMED): A traditional mass-production system would run a process as long as possible while building up a large inventory before breaking off to reset the process for another product. Building to schedules allows this and it was assumed that the time to change tools was invariable (and generally quite long); therefore, efforts were made to set schedules to minimize changeover frequency in order to minimize wasted time. Producing "just in time" however does not allow the building up of inventory and process changeover must be quick and frequent.

- Standardization to perfection: In a Lean company, there is a standard way to do everything, so that everyone is required to work to this standard practice. As the goal for Lean is "Perfection", Standardization is seen as an essential to allow improvement, so that everyone is using the best methods identified so far.

- Participation and continuous improvement: Continuous Improvement efforts are required from everyone, at all levels in the company. Suggestions for improvement are made and then checked out to see if they really do reduce waste and improve the process. If they do, then standard work will be revised to implement the improvement.

4.2 Principles Of Lean

- Reengineering the Manufacturing System: Reorganizing fabrication and assembly systems into cells that produce families of products. The cells should have one-piece parts movement within it and small-lot movement between them, achieved by creating a linked-cell system.
- Setup Reduction and Elimination: Setup time for a cell to be less than manual time, or the time a worker needs to load, unload, inspect, etc.
- Integrate Quality Control into Manufacturing: The operation is "Make-one, check-one, and move-on-one" type; and the quality of products output from the system has to be 100%.
- Integrate Preventive Maintenance into Manufacturing: There has to be no equipment failure and the workers must be trained to perform routine low level process maintenance.
- Level, Balance, Sequence and Synchronize: Fluctuations in final assembly should be eliminated, outputs from cells have to be equal to the necessary demand for parts downstream and the cycle time must be equal to take time for final assembly.
- Integrate Production Control into Manufacturing: Cells respond to demand by delivering parts and products only as they are needed, or just in time.
- Reduce Work-In-Process (WIP): Minimize the necessary WIP between cells, and parts are handled one at a time within cells.
- Integrate Suppliers: Reduce the number of suppliers and cultivate a single source for each purchased component or subassembly.
- Automation: Inspection becomes a part of the production process (100% inspection) and there should be no overproduction.
- Computer-Integrated Manufacturing: Production system to be as free of waste as the manufacturing system.

V. ENVIRONMENTAL BENEFITS ARISE FROM ELIMINATING LEAN WASTES

Lean implementation efforts can create powerful coattails for environmental improvement, since environmental impacts are embedded within the production wastes targeted by Lean as listed in Table (1). Therefore, reducing these Lean wastes, produces environmental gains. For example, less over-processing and more efficient transport results in lower emissions. In addition, less storage and inventory space from the creation of right-sized production unit, results in reduced materials, land, and energy consumed.

Lean produces an organizational culture that is highly conducive to waste minimization pollution prevention, environmental management systems, and sustainability.

VI. SEVEN MOST COMMON WASTES

Table(1): Environmental Impacts of Lean's "Deadly Wastes"

Lean Waste Type	Environmental Impacts
Overproduction Manufacturing items for which there are no orders	- More raw materials and energy consumed in making the unnecessary products -Extra products may spoil or become obsolete requiring disposal -Extra hazardous materials used result in extra emissions, waste disposal, worker exposure, etc.
Inventory Excess raw material, work-in-process, or finished goods	-Raw materials and energy consumed in making defective products -Defective components require recycling or disposal - More space required for rework and repair, increasing energy use for heating, cooling, and lighting
Defects Production of off specification products that result in rework and/or defective materials	-Raw materials and energy consumed in making defective products -Defective components require recycling or disposal -More space required for rework and repair, increasing energy use for heating, cooling, and lighting
Transportation - Excess transport of WIP or products. ***Motion*** - Human movements that are unnecessary	-More energy uses for transport -Emissions from transport - More space required for WIP movement, increasing lighting, heating, and cooling demand and energy use -More packaging required to protect components during movement -Damage and spills during transport -Transportation of hazardous materials requires special packaging to prevent risk during accidents
Over processing Process steps that are not required to produce the product	-More parts and raw materials consumed per unit of production -Unnecessary processing increases wastes, energy use, and emissions
Waiting Delays associated with stock-outs, equipment downtime, capacity bottlenecks	-Potential material spoilage or component damage causing waste -Wasted energy from heating, cooling, and lighting during production downtime

Industrial Building Design Guide Lines		Lean Principles										Sustainable Architecture Principles									
												Cost efficiency			*Human adaption*			*Resource conservation*			
		Reengineering the manufacturing system	Setup reduction and elimination	Computer-integrated manufacture	Reduce work-in progress	Level, sequence and synchronize	Integrate suppliers	Automation	Integrate production control into manufacturing	Integrate preventive maintenance into manufacturing	Integrate quality control into manufacturing	Initial cost	Cost in use	Recovery cost	Protecting human	Protecting physical resources	Urban design & site planning	Energy	Material	Land	Water
Environmental	Sustainability	1	4	0	3	2	3	2	3	1	2	5	5	5	5	5	5	5	5	5	5
	Healthy	1	4	5	4	2	5	4	1	4	5	1	2	3	5	4	5	4	3	2	5
	Thermal comfort	2	4	1	4	2	1	4	3	3	5	2	5	5	5	2	1	5	3	1	4
	Acoustically	3	4	5	4	2	1	2	2	5	3	4	1	3	5	4	1	2	4	1	1
	Day lighting	1	3	2	4	4	1	3	2	2	4	4	5	5	5	5	3	5	2	1	1
	Ventilation	1	3	1	3	1	1	3	3	3	4	5	5	5	5	5	3	5	3	4	2
Aesthetical	Unity	1	4	2	5	3	1	5	4	4	3	3	1	4	1	1	4	3	3	4	2
	Historically	1	1	1	3	3	1	3	1	1	1	1	1	1	3	3	5	1	4	4	1
	City regulations	1	1	1	1	1	4	3	1	1	1	3	3	1	3	3	5	3	1	5	3
	User comforts	3	3	3	4	2	4	4	2	2	2	2	4	4	5	3	3	3	2	2	4
	Innovation	4	4	3	4	1	1	5	2	2	5	5	5	5	4	4	4	5	4	3	3
Functional	Flexibility	5	4	1	3	3	3	5	2	4	2	2	5	5	3	4	5	3	2	4	1
	Accessibility	1	3	1	3	1	3	1	3	4	5	1	3	3	3	1	5	3	2	3	1
	Employees accommodation	2	2	3	4	2	3	3	4	4	4	1	3	1	5	1	5	4	2	4	4
	Relationship	2	1	1	5	1	2	5	4	3	4	2	4	2	3	2	4	2	1	2	1
	Plant development	4	3	3	5	5	2	5	4	4	5	1	4	5	3	4	5	4	3	4	
Economical	Cost Effective	3	4	3	5	5	2	5	4	3	5	5	5	5	1	2	3	4	4	4	3
	Zero waste study	3	4	3	4	3	3	4	4	4	5	5	5	5	2	2	4	5	5	5	5
	Efficiency	3	4	3	3	4	3	3	3	4	4	5	5	4	2	1	4	5	5	5	5
	Land reduction	3	4	3	5	4	2	4	3	3	3	5	5	5	2	4	5	4	4	5	2
	Efficient technology	5	5	5	5	4	3	5	4	4	5	3	5	4	1	2	3	5	3	4	4
Building Operation	Safety	3	1	3	1	2	1	4	3	3	4	3	4	4	5	5	3	4	4	1	2
	Security	1	1	3	1	1	3	1	2	2	4	2	3	1	4	4	3	1	2	3	1
	Fire protection	3	1	3	1	1	1	4	2	3	3	4	3	4	5	5	3	3	3	1	4
	Resist natural hazards	3	1	1	1	3	4	4	2	2	1	1	3	1	4	3	5	3	4	4	4
	Grime Prevention	1	1	2	2	2	3	1	2	1	3	2	3	4	4	4	4	3	3	4	3
	Resist natural hazards	1	1	2	2	2	3	1	2	1	3	2	3	4	4	4	3	3	3	4	3
	Watering & Drainage	2	1	1	2	3	1	3	2	4	3	4	5	3	4	3	4	4	4	4	5
Industrial Production	Transportation	2	1	1	4	2	4	1	2	3	4	3	4	1	2	2	4	4	2	3	1
	Productivity	3	2	2	5	2	3	4	5	3	5	1	5	3	1	1	3	5	2	2	3
	Quality control	2	2	2	2	4	2	5	3	4	5	4	4	4	3	2	2	5	4	2	4
	Maintenance	1	3	2	2	3	1	3	2	5	4	2	3	5	1	1	1	3	4	2	2
	Synchronizing	2	3	2	4	5	3	2	4	3	4	3	5	5	3	3	4	5	4	4	5
	Automation	4	4	4	4	1	2	5	3	4	5	4	4	4	3	3	4	5	3	4	2

VII. SIX SIGMA

7.1 DefInition

Six Sigma refers to a set of well-established statistical quality control techniques and data analysis methods used to identify and reduce the variation in products and processes. Sigma is a letter in the Greek alphabet which represents the standard deviation of a statistical population, so “six sigma” denotes a target level of quality that is six times the standard deviation. This means that defects only occur approximately 3.4 times per million opportunities, representing high quality and minimal process variability. By using Six Sigma statistical tools, companies are able to diagnose the root causes of performance gaps and variability, so that it improves productivity and

product quality. In addition to a high-return improvement results in continuous improvement and significant financial gains.

7.2 the steps in the six sigma DMAIC process

- Define: In this phase, Six Sigma teams focus on defining the problem statement, including project improvement activity goals and identifying the issues that need to be addressed to achieve a higher sigma level.
- Measure: In the Measure phase, the aim is to gather information about the targeted process. Metrics are established and used to obtain baseline data on process performance and to help identify problem areas.
- Analyze: This phase is concerned with identifying the root cause(s) of quality problems, and confirming them using appropriate statistical tools.
- Improve: During the Improve phase, teams work on the identified problems by implementing creative solutions. Sometimes Lean methods, such as cellular manufacturing, 5S, mistake-proofing, and total productive maintenance, are identified as potential solutions.
- Control: In the final phase, teams work to institutionalize the improved system by modifying policies, procedures, and other management systems. Process performance results are again periodically monitored to ensure productivity improvements.

VIII. CELLULAR MANUFACTURING TAXONOMY

A CM production system is a network of linked cells. Hence throughput of cells can be dependent on a single machine's cycle time or on the speed of the material handler or operator. For this system some parameters must be studied before implementation they are;

- Changeover Time: The length of time a machine or processing area is down (not producing parts) in order to change over from one part type to another.
- Customer Lead Time: The length of time begins when a customer places an order and ends when the customer receives goods to fill that order.
- Defects vs. Errors: A defect is a product or service's non-fulfillment of an intended requirement or reasonable expectation for use.
- External Setup Operations: Operations in changeover from one part type to the next which are done while the machine is still producing parts. Similarities: (1) part geometry, or (2) processing similarities. GT is generally used.
- Final vs. Absolute Defect Rate: the final defect rate reflects only the number of parts that fail the final inspection. However, the absolute defect rate is a measure of the number of defects for the entire process from start to finish.

Flexible Manufacturing System (FMS): A group of numerically controlled machine tools interconnected by a central control system

IX. STUDY MODEL APPLICATION (AFF FACTORY)

Design development was done for a flavor additives and fragrance factory. The industrial building design guidelines have been achieved by applying sustainability and lean manufacturing principles together.



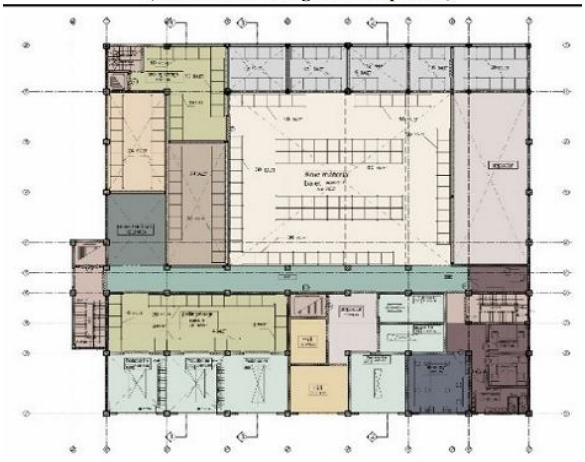
Fig(1): GROUND FLOOR PLAN (Before Arch. Design Development)



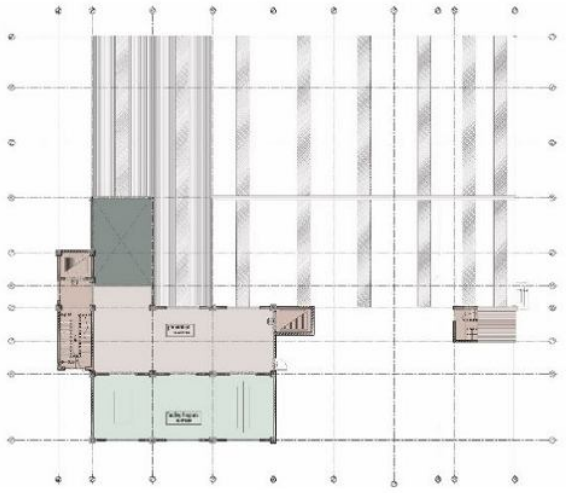
Fig(2): FIRST FLOOR PLAN (Before Arch. Design Development)



Fig(3): GROUND FLOOR PLAN (After Arch. Design Development)



Fig(4): FIRST FLOOR PLAN (After Arch. Design Development)



Fig(5): SECOND FLOOR PLAN (After Arch. Design Development)

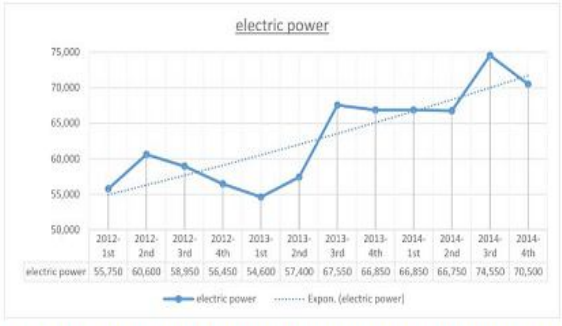


Fig(6): SECTION A-A

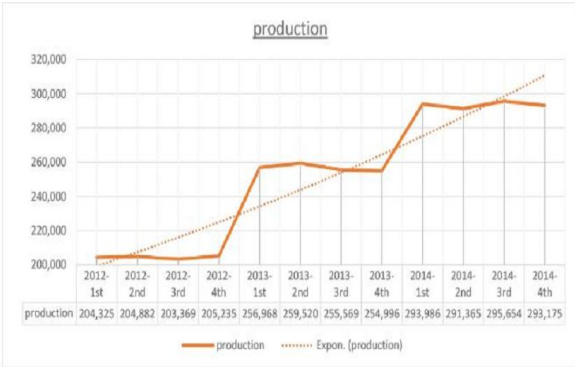


- The fabrication system was re-organized into cells which have one-piece parts movement within the cell and small-lot movement between cells was also achieved by creating a linked-cell system.
- Each cell has its own warehouse and also there are warehouses which are designed for daily and weekly usage in addition to the general one.
- The outer warehouse areas were minimized for the factory to be 600 m^2 after it was 1200 m^2.
- The end product warehouse is separated into two spaces for savory and sweet products. Its stacks were designed to hold an equivalent number of products to those which come out from the product lines.
- The setup time was reduced to be less than the manual time by eliminating the unneeded number of workers within the cell. As after applying the new design there are only two workers are needed to manage the upper level of the three production lines (number 3, 4 and 5) as shown in figure (5). Two workers are needed to manage the main raw materials warehouse, one worker to manage the end product warehouse and one worker is needed to receive the product in each product line.
- Quality control has been integrated within the manufacturing system of products in order to meet the ultimate standards. Therefore, the quality of products output from the system is to be 100%.
- The defected or rejected products have been recycled in order to achieve zero waste theory.
- The electric power consumption was reduced by; selecting less power consuming machinery, using suitable thermal insulators for steam and hot/cold, insulating the building externally as well as insulating surfaces and also changing all lamps to be LED lamps in order to reduce the consumption.
- Moveable partitions were used in the main warehouse in order to separate between different spaces as needed so that we can reduce the consumption of electricity used for artificial lighting and ventilation.
- The whole roof of the building was thermally isolated by sandwich panels while the walls was isolated by using cavity walls of lime stones in order to get the optimum temperature in order to reduce the consumption of power which is needed in the operation of balancing the internal heat.
- Back filters were set opposite to wind direction in order to avoid the pollution of the surrounding areas.
- Raw materials, employees and end-products entrances and exits were designed in a sequence which serves the manufacturing flow. Also sterilizing areas are found in front of each entrance as all working spaces are sterilized.
- The area of the services spaces was minimized and also staircases are found in order not to obstacle the manufacturing flow in case the elevators need to be maintained.
- Internal maintenance center is found inside the factory which consists of one engineer and two technicians.
- The Firefighting system is supplied by ground water tanks which are supplied from the desalination unit and the underground water pump applied in the site.

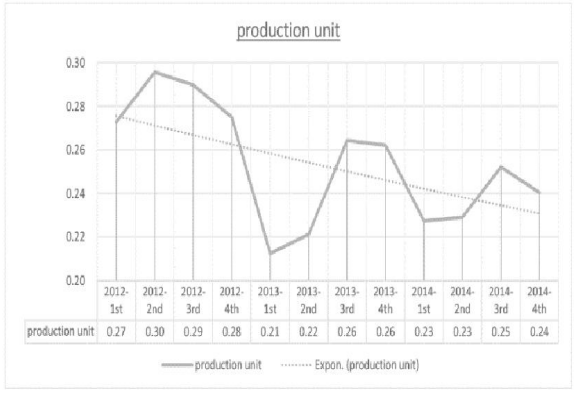
X. ANALYSIS OF FACTORY READINGS AFTER DESIGN DEVELOPMENT



Fig(7): Graph to indicate the change ofconsumption of electric power over years



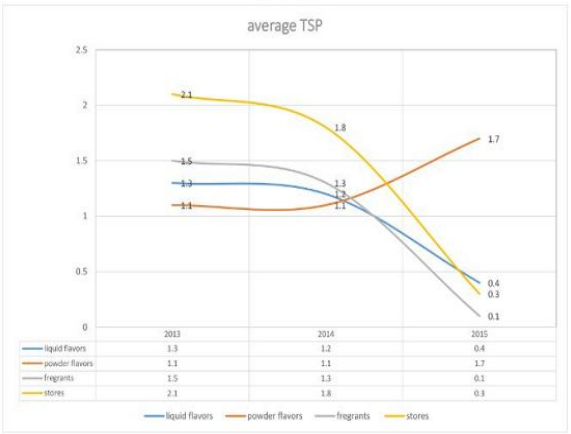
Fig(8): Graph to indicate the changes of production rate over years



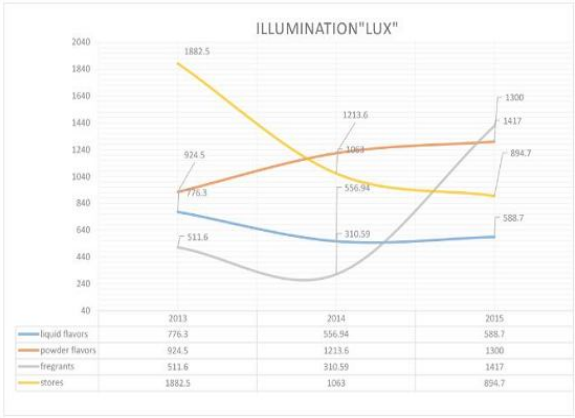
Fig(9): Relationship between Factor power and Production unit



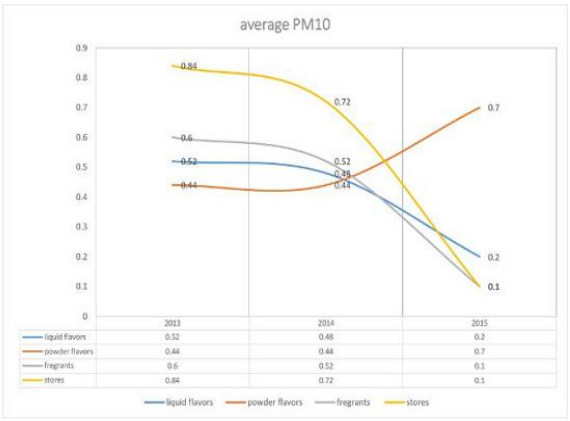
Fig(10): Relationship between production value and number of workers



Fig(11): Graph indicate the Air Pollution values over years



Fig(12): Graph to indicate The Illumination values over yearss



Fig(13): Graph to indicate Air Quality over years

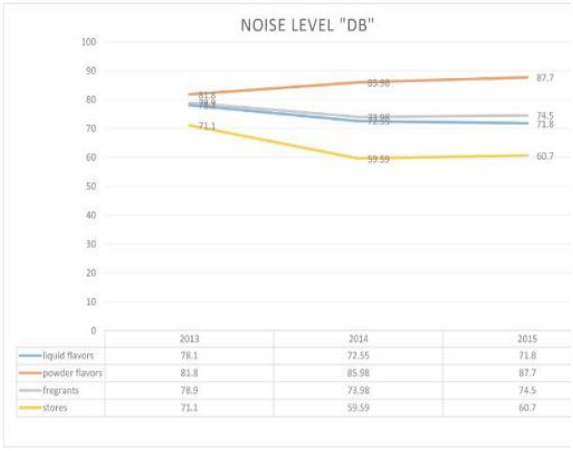
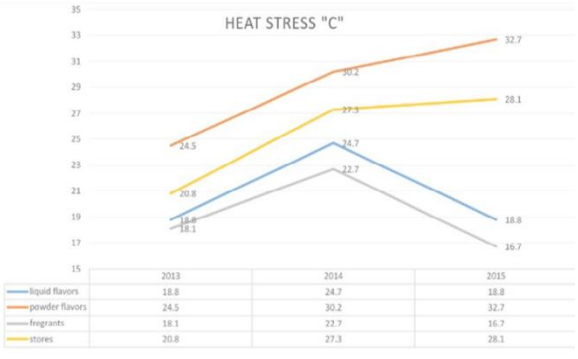


Fig (14): Graph to indicate Noise level changes over years



Fig(15): Graph to indicate Heat stress variation over years

XI. CONCLUSION AND RECOMMENDATIONS

1 The industrial building design guidelines criteria which are based on several factors such as environmental, aesthetical, functional, economical, building operation and industrial production should be used in the design process.

2 Achieving Lean and Sustainability principles through the architectural design process should be taken into consideration.

3 The general principles of Lean and sustainably are considered to be similar and integrated with each other. So that it can be applied easily and homogenously.

4 The Architecture design process affects the achievement of Lean principles with variable rates. Also, it works effectively and clearly on achieving sustainability principles.

5 After the execution of the renovated phase of the factory according to the study, industrial and environmental measurements have been recorded. So it was found that:

- The relation between production rates and number of workers has been raised after the development process
- The relation between the increasing energy consumption and production rates is directly proportional.
- Dividing both of storage areas and production lines is inversely proportional to the rate of reducing energy.
- Local natural materials that act as a thermal insulator are used in the environmental treatments in order to achieve the principles of sustainability.
- Recycling of the industrial drainage water by desalination to be used in irrigation and cleaning processes in order to achieve the principles of sustainability.

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