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Facility Layout: As a Tool for Clean Production and Eco Efficiency

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Abstract- Within the scope of sustainable development eco efficiency and cleaner production are new subjects for diminishing the industrial waste and increasing the productivity. They are broad topics. Eco efficiency philosophy aims decreasing usage amount of energy, water, raw materials during production cycle without decreasing quality of produced products. Because of less energy, water and raw material usage it provides environmental productivity (less pollution). Clean production, philosophically serves similar purpose. Clean production is minimizing the amount of waste on source of waste. It deals with eco design, good purification, and environmental friendly production processes. Diminishing amount of waste and pollution provides environmental productivity but also it provides economic productivity because of decreasing waste treatment cost. These subjects are generally linked with environmental sciences because they are about diminishing occurrence amount of waste and waste treatment. But also those subjects are related with productivity (industrial engineering). In this study, an industrial engineering subject which is Facility Layout is reviewed as a tool for eco efficiency and clean production.

Keywords- Facility layout, clean production, ecology, eco-efficiency

1. Introduction

By the beginning of the new millennium Sustainable Development gained more popularity. Amount of resources are diminishing. World population and their needs are increasing. For satisfying these demands, producers use more raw materials, more water and more energy. That causes more pollution. If this demand and supply cycle continues like this, it is going to be hard to satisfy demands of future generations. Besides that pollution of earth is going to be increased. Because of these reasons, some new philosophies and methods are developed to alleviate this big problem. Eco efficiency and clean production are few of them.

During production processes lots of activities are implemented. They can be physical reactions and chemical reactions. All these activities cause some wastes. Waste creation causes poor economic productivity and environmental productivity.

Waste is a material that we never want to produce. But we come across this problem in every step of product life cycle. At design stage of product design, materials that compose the products are determined. They should be designed as environment friendly (easy to recycle) for providing environmental productivity. This is about customer view. In fact, in this study it is dealt with production part of product life. Production process stage includes lots of activities which vary according to produced product. Every activity of production could create waste. Those wastes may come from residual raw materials, process water, using unnecessary amount of energy, much noise, dirty gas, unnecessary number of employees and equipment. As it can be imagined, this is also a productivity problem. Therefore these pollution problems are also related to industrial engineering subjects such as ergonomics, quality engineering and facility layout ect.. In this study we aim to draw the link between clean production and eco-efficiency with facility

layout method by examining the general nature of these subjects

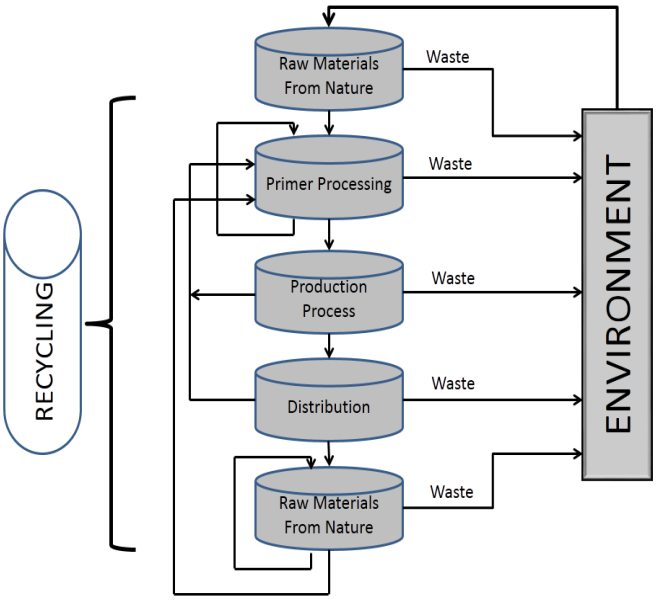

Figure 1. Relation between environment and supply chain (Tepe and Uludağ, 2002)

2. Literature Review

In literature review section, links between eco-efficiency, clean production and facility layout subjects were investigated. Clean production and eco- efficiency and clean production are subjects of sustainable development issue. That is why early and most of later studies about those subjects belong to environmental and chemical engineering researchers. However those subjects are broad topics. They involve lots of disciplines according to their particular cases. This research involves examination of clean production and eco-efficiency tools.

Research studies dealing with investigation of clean production methods were ordered chronologically. In 2003, a study in Norway focused on the intangible benefits and human factors derived from clean production projects, how the present clean production model could be improved and current ideas on how the clean production concept could be expanded to more directly address the needs of developing countries Improvements to the present clean production model should include means for ensuring sustainability of the local clean production center and its activities and financial mechanisms to facilitate affordable environmental investments. This study handled Clean production in a wide concept and tried to encourage the development of a "holistic view". It examined new job opportunities and how clean production concept integrated with foundations (Kjaerheim, 2003). Although this study examines new job opportunities and other trends which support clean production applications, it does not mention importance of plant layout in point of incensement of clean production performance. As it can be easily understood successful clean production projects provide profitability. A significant study was made that represents the link between clean production and profitability by examining 132 industrial pollution prevention projects (Cagno et al, 2003). Hierarchical pollution prevention 1990 U.S. is illustrated that was first defined in October 1990 U.S.

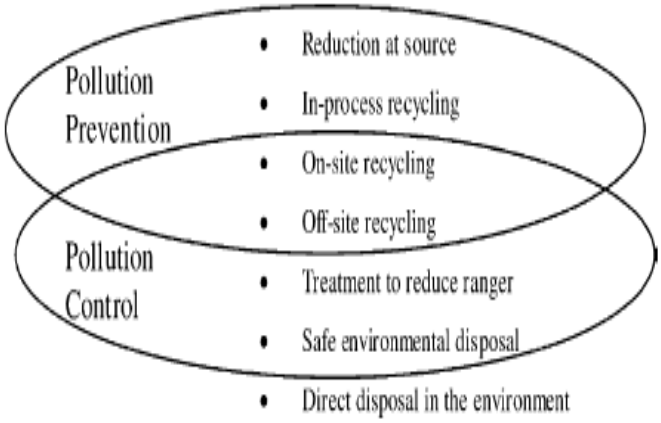

Figure 2. Evolution of the methodologies to design and manage eco-efficiency (Cagno et al, 2003).

In the view of our research we believe that examining reducing at source is more important than other methods. "Reducing at resource" philosophy has two components. One is reducing the amount of dangerous and contaminating substances which is used in production process and in the composition of waste. Second is reducing the variety of waste. Main techniques for "reduction at resource" are listed as below;

- improved operations in the factory;
- recycling of waste within the process;
- process modification;
- replacement of materials and products;

- separation of waste materials.

As it is seen plant layout design is not involved in the list (Cagno et al, 2003). At the conclusion part of study Cango and colleagues admit that clean production perception of companies change towards being a strategic issue. That intent is mostly because of cost reduction desire. Therewithal, it is observed that pollution prevention activities are still in the early stage, mainly based on pilot projects that are empirical and not completely integrated into the management processes.

Because clean production and eco-efficiency are multidisciplinary subjects, holistic view is very important. A generalized multi-objective process model is proposed that does modelling and optimization with environmental impacts and economic aspects simultaneously by Jia and others. A hybrid multi-objective evolutionary algorithm is used for solving the case of simple reaction system. In fact, main goal of this study is developing a decision support system for optimizing cleaner chemical production processes. Originality of this system is consideration of environmental impacts and economic aspects simultaneously. First, the chemical process was analyzed. Second, a generalized multi-objective mathematical model was developed for a process with environmental impacts and economics aspects (Jia et al, 2006). Model variables can be represented as below;

Table 1 Model parameters and variables
(Jia et al, 2006)

Nomenclature

$\boldsymbol{e}$	energy matrix [kJ]
$\boldsymbol{E}$	energy transformation matrix
f	objective function
F	flowrate [mol/h]
$\boldsymbol{H}$	enthalpy matrix [kJ/kg]
$\boldsymbol{\Delta H}$	enthalpy change matrix [kJ/kg]
$\boldsymbol{m}$	mass matrix [kg]
$\boldsymbol{M}$	mass transformation matrix
$\boldsymbol{m}^*$	environmental impact potentials
T	temperature [K]
$\boldsymbol{w}$	weight matrix
x	conversion
X, Y, Z	components

Subscripts

I	input
O	output
R	reactor
S	separator/recycle
P	product processing
V	energy recovery
A	energy processing
B	material processing
W	waste treatment

This model is developed to provide eco-efficiency for a chemical process plant. It only deals with process dynamics. Although it was proposed to consider both economic and environmental aspects in a holistic view, industrial engineering view (like plant layout or other quality improvement techniques) were not included in the model.

Another study which examines the link between clean production and productivity was made in China. Increasing of business performance is a good motivation factor for applying clean production and eco-efficiency projects but it should be analyzed properly. Zeng (2010) developed a model which represents the relationship between cleaner production and business performance was analyzed using Structure Equation Model (SEM). Zeng and others also impressed the financial view. High-cost and low-cost clean production activities were examined in Chinese manufacturing industry.

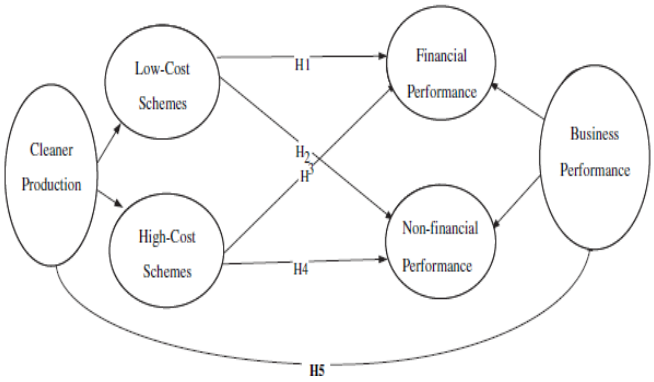

Figure 3. Relationship between cleaner production and business performance (Zeng et al, 2010).

One of the most important contribution of this study and which also related to our current study is the fact that cleaner production activities of low-cost scheme have a bigger contribution to financial performance, compared to non-financial performance. The reason is that the low-cost scheme cleaner production activities do not require significant financial input but may bring immediate financial benefits. So, as it is noticed that using energy efficient and clean technologies require significant financial investment but may not result in immediate economic benefits (Zeng et al, 2010). On the other hand some process redesign and employee training solutions provide more economic benefit than other high-cost techniques. Because facility layout is a low-cost productivity improvement method (which supports energy, raw material and time saving), it should be considered as a clean production technique. Indexes of clean production that study used was represented as below;

Table 2 Indexes of clean production (Zeng and others, 2010)

Evaluation index	Code	Index depiction
Low-cost scheme	CPL1	Improve employee environmental consciousness through training and evaluation
	CPL2	Improve working conditions to reduce waste
	CPL3	Strictly enforce rules on cleaner production
	CPL4	Enforce cleaner production as a long-term and continuous policy
	CPL5	Increase the recyclability of the products and components.
	CPL6	Possibilities of reducing the use of packaging are considered
High-cost scheme	CPH1	Possibilities of using energy efficient and clean technologies are considered
	CPH2	Possibilities of using renewable resources are considered when selecting raw materials and energy;
	CPH3	Increasing the durability of the products is considered;
	CPH4	Increase investment for environmental protection
	CPH5	Environmental issues are considered in the processes of production planning and technology innovation

Process monitoring and optimization are very important in terms of clean production and eco-efficiency. Klemeš (2012) made a research about recent cleaner production advances in process monitoring and optimization. Their study argues that decreasing CO_2 emission is a very important subject for clean production. On the other hand better product design, better process optimization, better monitoring, better training and management combined with improved governmental policies are effective tools for clean production.

SME's are very important economic and environmental actors in every country. Their environmental awareness is not as much as big companies. So they need encouragement. In Venezuela, a research was made which reviews public administration for encouragement tools and how they contribute to overcoming barriers to eco efficiency by offering external and internal incentives for SME. They assessed those tools based on criteria like: market influence, capability of the public administration for controlling results, tool costs, impact on public administration image, timespan to get results, etc. Finally they listed the public administration tools for eco-efficiency according to their suitability;

- Taxes
- Protection of Areas and Species
- Advertising of responsible consumption & eco-efficient products
- Subsidies
- Education in environment:
- Limit legislation
- Research in environment
- Legislation of BAT
- Green procurement policy
- Voluntary agreements
- Product panels
- Environmental Declarations (Fernández et al, 2013)

In this literature survey, eco-efficiency and clean production methods were researched comprehensively. Industrial engineering methods were not clearly considered by researchers. Facility layout subject has never mentioned either. In the following part eco-efficiency and clean production considerations will be defined briefly.

3. Eco-Efficiency and Clean Production Considerations

Within the scope of sustainable development environment and economic efficiency have begun to be considered together in order to encourage company owners. Eco-efficiency and clean production subjects are good examples for that because these production philosophies consider operational productivity and waste management. In the view of social and ecological responsibility governments and United Nations support applications of these methods by financing the projects and by training employees and engineers ect... Besides that those subjects are very important for company owners as they are closely linked by resource optimization. To define these methods and to have noticed the link between industrial engineering methods such as facility layout, it is listed some matters.

"There are ten core environmental considerations at the heart of eco-efficiency (Jung et al, 2001):

- using materials with less environmental impact
- using fewer materials overall in the manufacturing of products
- using fewer resources during the manufacturing process
- producing less pollution and waste
- reducing the environmental impacts from distributing products
- ensuring that products use fewer resources when they are used by end customers
- ensuring that products cause less waste and pollution when in use
- optimizing the function of products and ensuring most suitable service life
- making reuse and recycling easier
- reducing the environmental impact of disposal"

Second important stage of clean production and eco-efficiency is production of this eco-designed product suitable for environmental and economic productivity. A clean production process which is related to sustainable development should consider good waste management. Besides that it should consider energy and water usage optimization, quality engineering, inventory management, capacity management, supply chain management ect… That part of clean production and eco-efficiency process is closely related with industrial engineering subjects. Because productivity (using less raw material, energy, water and time without diminishing quality of product) yields cleaner production. Unfortunately industrial engineering techniques have not considered by clean production and eco-efficiency researchers. (In this study, we introduce an industrial engineering technique which is "Facility Layout".)

Third stage of clean production and eco-efficiency is waste management. As it was mentioned before we produce waste besides our products. Those wastes cause poor environmental and economic productivity. Waste treatment is the final task of clean production concept.

4. Facility Layout; As a Clean Production and Eco-efficiency Tool

In production plants, there are lots of resources (raw materials, water, energy, workers and also time) used for production. Their usage amount and style cause conflict most of time. After designing of product, production process is derived according to satisfy future demand. By keeping a certain capacity and certain quality of product; a production system is designed. Production engineers have to determine the amount of equipment, workers, energy, water and space needed for implementing production process. At that point facility layout techniques have benefits for solving this problem. "Manufacturing facility design is the organization of the company's physical facilities to promote the efficient use of company's resources such as people, equipment and energy" (Meyers and Stephens, 2005). This productivity improvement technique has some particular goals and most of them are related with clean production and eco-efficiency concepts. Facility layout goals are also related with eco-efficiency and clean production goals. In this part of paper, it is investigated. Facility layout projects provide firms those aspects shown below;

- Minimizing Unit and Project Cost: This means selecting most suitable equipment in order to minimize production cost. Number and skills of machinery and equipment have to be optimized according to capacity and total demand of product. That diminishes waste caused by machinery and equipment which provide eco-efficiency.
- Optimizing Quality: Quality is a very important concept for manufacturing. When designing the production plant, designing engineers consider quality characteristics of products. They choose the machines which are compatible with each other and have success at producing less variability. Increasing quality provides benefits in terms of eco-efficiency and clean production. Increasing quality by way of quality engineering causes reduction of variability of process outputs and decreases scrap and rework.
- Promoting Effective Use of People, Equipment, Space and Energy: This is the main reason for making a plant layout project. That is all about productivity. If a production plant is designed according to facility layout techniques, it needs less space, workforce and energy. Facility layout projects decorate inside of plant. It diminishes the total distance of raw materials and semi-products on the production line. So it requires less space and energy. Facility layout projects also consider ergonomics of working environment. They design the working environment with adjusting optimum noise, temperature and so on. Selecting suitable furniture style is also important for ergonomics. Those adjustments provide less pollution and efficiency.
- Providing better safety for working environment: Facility layout has to consider good safety because it affects employee motivation positively. Thus, they think that they are being cared about. Actually human resource is the most valuable resource. If employees are well motivated in a factory, quality of outputs increases.
- Providing high production flexibility: Some factories produce more than one product to get benefit of economies of scope or they need to increase production capacity suddenly. Facility layout design increases the success of those firms because they are supposed to be designed flexibly for sudden changes. Otherwise layout design could be unwieldy and that causes poor productivity and much pollution when capacity and product type need to be changed (Meyers and Stephens, 2005).

In fact, facility layout is part of operations management job. Operating a factory is a complicated job. First you need a proper market research to understand "What customer wants?". After determining that an innovation or product redesign process start, products design process should be implemented with production process design simultaneously. That motion increases efficiency of production process. Capacity requirement of factory derives from future forecasts. Equipment selection is made in the light of this information. Finally, a last move is needed to increase production cost reduction and as it was mentioned in this study several times "minimizing the waste". That is a good facility layout. To make proper facility layout information about product needs, process needs, capacity needs are supposed to be known. As a summary it could be said that Facility layout is part of a big job.

5. Conclusion

Clean production and eco-efficiency are new research areas of sustainable development. So, generally those subjects are approached in the concept of waste treatment and environment engineering. There are some national centers around the world. UNIDO (United Nations Industrial Development Organization) is the leader of this subject. They are trying to introduce importance of these subjects, giving financial support and training. This multidisciplinary research area is open for development either. Clean production and eco-efficiency projects are implemented by a multidisciplinary team. It includes environment engineer, process engineer, product engineer and definitely industrial engineer. Each expert has important responsibilities job for implementing the project. One of the vital jobs of industrial engineer is designing facility layout. In this paper, it is concluded the importance of facility layout concept in terms of clean production and eco-efficiency. Further studies should integrate

other industrial engineering techniques to clean production and eco-efficiency.

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