Facility Layout optimization through Quality Function Deployment

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Abstract: - The paper addresses the critical concern of facility layout planning and design, driven by the imperative to maximize space utilization, enhance product flow, minimize manufacturing costs, and boost employee satisfaction. Effective facility layout design emerges as a cornerstone for achieving these objectives, contributing significantly to a company's overall success. It aligns production processes with strategic goals, optimizing spatial resources and fostering a conducive work environment. A central focus of this research is the exploration of Quality Function Deployment (QFD) as a tool for facility layout design. The author investigates its applicability across different industries, offering insights into its adaptation for specific needs. Case studies spanning sectors like healthcare, manufacturing, and education illustrate the versatility of QFD in addressing unique requirements. Ultimately, this study seeks to provide a generalized approach that can be readily tailored to meet the specific needs of any company, thereby advancing the field of facility layout planning and design.

Key-Words: QFD, quality, Facility Layout, optimization, quality management

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1 Introduction

The concern for facility layout planning (FLP) and design arises from the need to utilize available space efficiently, leading to improved product flow, reduced manufacturing costs, and increased employee satisfaction. Proper FLP can enhance a company's success by optimizing space, reducing costs, and creating a worker-friendly environment. FLP aligns production processes with strategic objectives.

Layout improvement methods include rerouting material flow for efficient movement and complete layout redesign. Various approaches exist for FLP and improvement, such as Systematic Layout planning, the firefly algorithm for cost reduction, and fuzzy logic for workforce optimization.

In the current paper, the author analyzed the possibility of using Quality Function Deployment (QFD) for facility layout design (FLD) and identified how it could be implemented by companies from various industries. The available literature focused on key case studies for companies from particular activity sectors such as hospitals and the health sector, some case studies covered the topic for manufacturing plants and some covered school layout design. In all of these cases, the QFD methodology was adapted for particular cases that met specific needs. The current research aimed at providing a more general approach that can be easily tailored for a company’s needs.

2 Problem Formulation

The need for efficient utilization of the available space has been a concern for both researchers and practitioners altogether.

In the current paper, the author looked at available literature regarding how this topic has been addressed and proposed a more generic model that companies can easily use as a starting point for FLP and designing which is based on the well-known QFD quality tool.

2.1 Literature review

The concern for facility layout rises from the need to ensure that a company is utilizing its available space the best way possible. Facility planning covers all aspects of organizing the facility, including the people, machines, tools and the available space in order to achieve a more efficient product flow that can reduce the cost of manufacturing and increase employee satisfaction [1]. Proper facility layout design has been linked to an increase in the success of a company [2] [3] by facilitating the optimization of space and locations which can lead to an optimization of the overall system's performance [4], a significant reduction of the production costs and a more worker-friendly ambience [5]. Furthermore, Planning FLP helps ensure that the production processes and factors are aligned with the organization's strategic objectives. [6]

In order to consider the most efficient solution for layout improvement, we must first understand the main types of facility layouts, each with its particularities suited for a specific type of activity. The four main types of FLD can be observed in Figure 1 [7] [8]. As it can be observed the four types of FLD are focused on the type of production process that the company has, ranging from large and individual products production to high volume production of standard products.

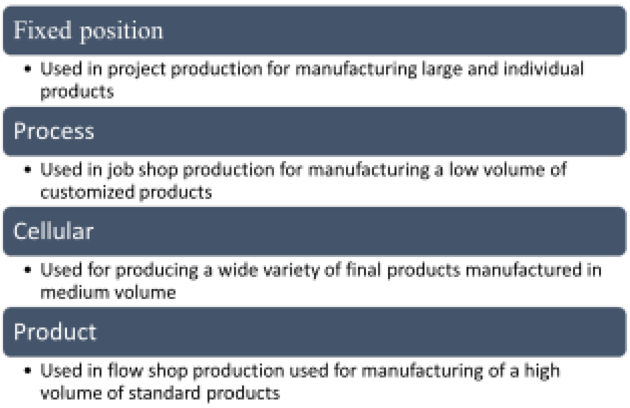

Fig.1 Facility layout types

When it comes to layout improvement methods, the available literature highlights two main alternatives: the re-routing of material flow which leads to an improvement in the efficiency of material movement, and the re-layout, a method that requires more time, effort and resources [7].

There is a significant number of approaches suggested by literature for facility layout planning and improvement. One such approach suggests the usage of Systematic Layout planning and ergonomic approach to design a FLD that can improve productivity in a sewing department of a company [9]. Another approach suggests the implementation of the firefly algorithm approach for FLD in order to reduce the material handling costs [10]. There has also been concern regarding the possibility of implementing fuzzy logic for workforce optimization while taking into account facility layout [11].

The possibility of using the QFD methodology for facility layout planning and design has also been taken into account by researchers analyzing the possibility of optimizing the functional and spatial design of emergency department in hospitals [12], for risk management in hospitals [13], improvement of facility layout problems in a manufacturing layout [14], the combination of Systematic Layout Planning (SLP) methodology and QFD for layout optimization and design in the case of service oriented physical distribution [15], and the application of Fuzzy logic and QFD methodology for solving the facility layout problem in the case of a school building [16].

2.2 Methodology

The QFD methodology was first used at Mitsubishi's Kobe shipyard in 1972, being quickly adopted by Toyota afterwards [17]. The core idea and basic philosophy of QFD is the integration of customer quality requirements throughout the production process and in the different stages of development. This integration of the customer "voice" in the product design and the production process pushes experts designing new products and services to become "translators" of the customer requirements in technical specifications which can be met by the company [18] [19].

The core of the QFD methodology consists in the application of the House of Quality (HOQ). The HOQ includes a matrix where the relationship between the customer requirements (also known as the "What") and technical specifications needed to meet those requirements (the "How") is highlighted [20]. A typical example of a HOQ (Figure 2) includes key elements such as: "Customer demands" and the priority level for each demand, the "Technical requirements" section with the desired direction of improvement, the "Correlation matrix" highlighting the interdependencies between all of the technical requirements, the "Relationship matrix" showing the relationship between the technical requirements and the customer demands, the "Technical assessment" segment where the final result of the intersection between the relationship matrix and the priorities levels is registered, and the "Benchmarking" section which allows a company to understand its position on the marketplace relative to that of its competitors.

This allows a company to not only design products that the customer desires and is willing to pay for, but also monitor quality closer and gain a deeper understanding of what the customer perceives as quality and what the most important technical requirements are.

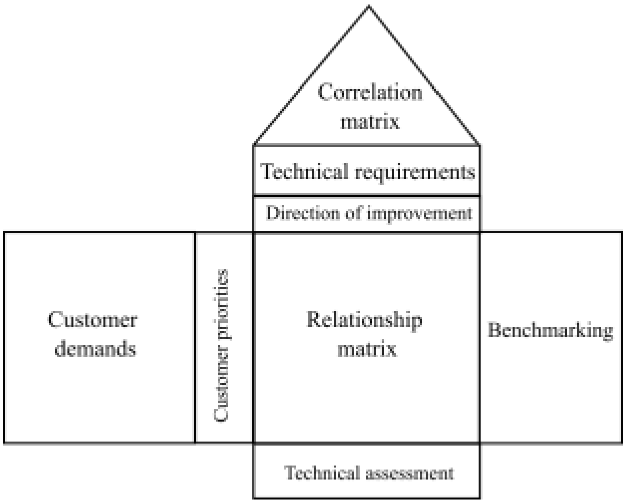

Fig.2 Classic example of HOQ

Throughout time, the HOQ has been modified in order to be used by companies working in different sectors of the economy. A modified QFD template has been used for addressing the requirements of startup companies working with Agile methodologies [21], integrating fuzzy logic and FMEA with QFD for selecting lean tools in manufacturing [22], combining QFD with fuzzy FMEA and AHP [23].

For the current research, available literature has been consulted in order to identify if similar concerns have been covered by previous research articles. The Web of Science (WoS) and Google Scholar databases have been reached for relevant literature by using the following search parameters: Topic: facility layout QFD; Title: QFD facility layout planning OR QFD facility layout design OR QFD facility design; Year: 2015-2023; Language: English. The WoS search query returned 5 articles that matched the criteria and which have been manually checked by the author for relevance and potential additional research sources. The Google Scholar search returned over 1000 results so the search parameters were adjusted to only include QFD facility layout design after which the papers were manually checked based on the relevancy of the article title and abstract.

In order to build the template HOQ presented in the Results section and which can be used by companies looking for an easy to use tool that can help determine the best FLD, the author examined the other applications of HOQ in FLD even if these were tailored for particular cases, identifying the features that could be seen as common and be applied by companies from various industries (features such as: worker health and safety, environmental concerns, waiting times, production flow, maintenance, handling and movement).

3 Results

The proposed HOQ variant for facility layout design takes into account not only the types of customer requirements that could emerge but also the features that could be used to satisfy these requirements and the relevance of the features for marginal customer satisfaction.

Another important difference is that although in the current form of the HOQ the benchmarking section has been eliminated, if considered necessary, it can be easily reintegrated.

The proposed model for the HOQ for a QFD used in facility layout design can be observed in Figure 3.

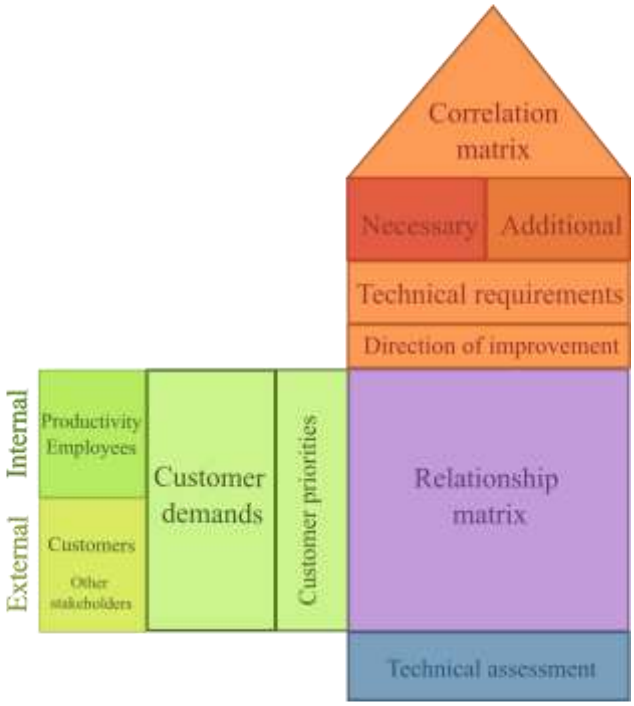

Fig.3 Proposed HOQ for facility layout design

As it can be observed, the model differentiates between internal and external customer demands, as well as necessary and additional technical requirements. Like so, internal customer demands are those coming from within the organization and which can be linked to internal targets and goals such as: employee satisfaction and retention, increase productivity and a decrease in costs with defects and reworks, end products that meet higher quality targets and so on. External customer demands focus on requirements gathered from existing or potential customers as well as input from any other existing stakeholders (such as governmental organizations concern regarding the environment impact of the company or facility).

Necessary technical requirements would in this case constitute minimum features needed in order to meet both internal and external customers while Additional technical requirements are concerned with meeting whenever possible the marginal customer (internal or external) satisfaction and contributing to the overall targets established by the company.

Figures 4 and 5 show a set of possible suggestions for entries in the case of customer demands and technical requirements, grouped based on the proposed classification that takes into account the internal and external customers as well as necessary and additional features for technical requirements.

Fig.4 Customer demands segment

As it can be observed, in the customer demands segment, for the “Internal Customers” subsegment, the following could be added: Lead time, employee satisfaction, cost efficiency, high production speed and reduced number of defects. For the “External Customers” subsegment Reliable products/services, Safety, Environmental impact, Technologies used and Market integration could be taken into account. Of course, these are mere suggestions aimed to help those using this model quickly identify key points, but these inputs can be modified and/or replaced to suit the necessities of the company looking to use it.

For the technical requirements segment a small number of features have been added to the figure for ease of representation. Additionally, the following could be included:

- For the “Necessary” subsegment: Space, Storage, Placement, Handling, Movement, Wait times, Health, Safety, Supplier contracts and relationships, Backup system, Transportation, In line inspection.
- For the “Additional” subsegment: Comfort, Low noise, Maintenance, Supervision, Integration of new technologies, Lighting, Addressing environmental concerns, Ergonomics, End of line inspection, Employee breaks.

Fig.5 Technical requirements segment

Just as in the case of the Customer demands subsegment, these are mere suggestions for possible technical requirements that could be taken into account when trying to consider the main aspects that need to be taken into account when designing a new facility layout meant to improve a company’s end result and productivity. That means that additional technical requirements can be added to suit the specific customer demands identified.

The proposed HOQ model for facility layout planning is highly abstract and therefore also highly customizable. The purpose of the model is to provide a quick assessment of the possible targets that a company could establish when it comes to facility layout improvement and design and the key aspects that should be taken into account when trying to address these issues.

After all of the customer demands have been identified and priorities have been set for each one of them (this can be achieved by asking customers to rank an already existing set of demands, or alternatively, asking customers to merely voice their demands and then identify which demands were the most common and assigning them the highest value), the team must decide which technical requirements are needed to meet the customer demands and also establish the direction of improvement for each of these requirements (for instance, the “Wait times” could be generally considered as needing to be shorter in order to facilitate the work flow and reduce employee dissatisfaction).

Once the customer demands and technical requirements have been noted, the rest of the matrixes of the HOQ can be filled the way a traditional HOQ would be, with the Correlation matrix identifying the correlations between the technical requirements, the Relationship matrix highlighting the relationship between each customer demand and technical requirement and the Technical assessment section providing an overall look of the state of the project, identifying which customer demands and technical requirements affect the desired outcome the most.

4 Conclusion

The concern for FLD arises from the need to optimize space utilization in a company. This includes organizing people, machines, tools, and available space in order to enhance product flow efficiency, reduce manufacturing costs, and improve employee satisfaction. Proper FLD has been linked to increased company success by optimizing space, reducing production costs, and creating a worker-friendly environment.

Two main layout improvement methods are highlighted in available literature: re-routing material flow for efficient material movement and re-layout, a more resource-intensive method.

There is a number of approaches in the literature regarding FLP and improvement. Such methods include Systematic Layout Planning and ergonomic approaches to improve productivity in the case of a sewing department of a company, using the firefly algorithm to reduce material handling costs, and implementing fuzzy logic for workforce optimization considering facility layout.

The proposed HOQ variant for FLD considers customer requirements, relevant features, and their impact on customer satisfaction. It distinguishes between internal (organization-related) and external (customer and stakeholder) demands, as well as necessary and additional technical requirements.

Necessary technical requirements are essential features needed in order to meet internal and external customer expectations, while additional technical requirements aim to enhance marginal customer satisfaction and contribute to the company goals. The proposed HOQ variant could prove to be a good starting point for companies looking to design their facility layout with the help of the QFD methodology.

The purpose of the paper and key points addressed by it within the context of modern systems theory refer to the following aspects: optimization of space utilization, enhancing product flow efficiency, reduction in manufacturing costs, improving employee satisfaction, layout improvement methods, highlighting various approaches to facility layout planning, providing a HOQ variant, technical requirements and the usage of QFD methodologies.

Possible future research directions include the integration of Industry 4.0 technologies in the design process for a facility's layout, the prospect of agile and flexible layouts that can easily adapt to changing product lines, processes and/or market conditions as well as approaches to human-centric design for FLP.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The author contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

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Conflict of Interest

The author has no conflict of interest to declare that is relevant to the content of this article.