Application of lean design in the planning layout of slab plant

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Abstract. Combined with the characteristics of planning and construction of slab plant, first of all, the article analyzes necessity of lean design in the planning layout of slab plant, then compares the characteristics of lean design and traditional layout, and proposes the theoretical framework of lean design in the planning layout of slab plant. Finally, the article takes changqing slab plant layout as an example, and verifies that the theory can achieve the goal of lean layout and provides guidance for similar facility layout planning.

1. Introduction
In China, high-speed railway is developing rapidly and high-speed railway construction is in full swing, CRTSII slabs are mainly used in high-speed railway construction. CRTSII slab has many characteristics, such as high technology, good integration and factory production, so it puts forward higher requirements for the planning and construction of slab plant[1]. In order to get an excellent planning layout of slab plant, the article introduces lean design into the planning layout of CRTSII slab plant, hopes to break through the traditional and empirical design method. What is lean design? It refers to the application of lean thinking in the design stage of the factory, combining lean thinking with traditional factory design, and integrating knowledge of optimization techniques, value engineering, systems engineering, computer technology and optimization algorithms to achieve the plant's scientific design[2].

2. Necessity of lean design in the planning layout of slab plant
The traditional railway construction method is slab cast-in-place, modern high-speed railway construction requires the production of all slabs in prefabrication plant and the delivery of the finished product to the construction site for assembly and installation. Compared with the traditional method, the advantage of prefabrication is to improve production efficiency, ensure product quality, and make full use of resources, but the disadvantage is that it must build additional temporary facilities to meet the needs of slab production. The common features of these facilities are large-scale (generally over 100 acres), high-cost, temporary, etc.[1] Therefore, the planning layout of slab plant must be the optimal design, the reasons mainly include the following aspects:

(1) Planning and construction of slab plant directly affect duration and investment of the project. The investment cost of the slab plant is high. Once the slab plant is built, it often cannot be adjusted or only a few adjusted, or can be adjusted but cost much. But considering the temporary, these huge cost is not worth, and excessive adjustment will affect the whole duration of the project;

(2) Slab plant is temporary, so it must be reclaimed after project completion, and reclamation cost is quite huge. The cost is directly related to the utilization of land resources, so at the beginning of the slab plant design, it must fully consider all possible influencing factors. Through rational planning, it
is possible to maximize production capacity under limited land resources, or to save land resources as much as possible while meeting production capacity;

(3) Slab plant layout lacks the characteristic of continuous improvement. General factory layout can improve the existing deficiencies through continuous improvement, so even if the existing layout design is not the best, it can be made up by continuous improvement in the later stage. Because slab plant is temporary, it coexists with the project of high-railway construction, namely, it is constructed before the project and it is torn down or other used after the project completion. Therefore, there is no significance in the continuous improvement of slab plant layout.

According to the literature at home and abroad, the theoretical research and application of lean production is quite mature[3][6], while the research on lean design is relatively rare. In order to eliminate waste at the beginning stage, the lean thinking is extended to the design, and the lean thinking is fully applied from the plant design stage, so waste is eliminated as much as possible from the plant design stage, truly realizes the essence of lean thinking.

To sum up, there are similarities between slab plant layout and lean design, therefore, this article applies lean design to layout design of slab plant, and puts forward the lean design in the planning layout of slab plant.

3. Characteristics of lean design in the planning layout of slab plant

In this article, lean design in the planning layout of slab plant is proposed to better achieve these goals such as project quality, duration, cost, safety and environmental protection of railway construction, which has more obvious advantages than traditional layout design[2][7].

| Item    | Lean design layout                                                                 | Traditional layout                                                                 |
|---------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Goals   | Lean design is introduced at the design stage of the slab plant, waste is eliminated from the source, and the planning design is the optimization. | The traditional method completes the layout design according to the requirements of slab plant, usually only meet the project duration and process flow. |
| Implementation | Lean design layout integrates lean thinking, optimization technology and computer technology to make it more objective. | The traditional method is guided by the expertise of traditional planners and relevant experience, and has a strong subjectivity. |
| Members | The design institute, lean thinking talents, business managers join the design team. | Only design institute, limited communication with other relevant personnel. |
| Effects | Lean design layout introduces lean thinking in the early stage to get optimal layout design, it can effectively save land resource and improve efficiency. | The traditional method lacks optimal layout design, various types of costs are increased, and the production capacity is insufficient. |

Figure 1. Process of lean design in the planning layout of slab plant.
4.1. Set up a team of lean design

In order to better implement layout lean design of slab plant, we need to establish a team, team members mainly include talents of lean knowledge, professionals of layout planning, the relevant leaders, staffs who have slab plant construction experience, managers, foreign consultants, etc. They communicate with each other and form a knowledge set of lean design in the planning layout of slab plant, to guide the implementation of lean design.

4.2. Determine key parameters

Lean design requires the optimization of key parameters, that is, under the premise of ensuring the project duration and quality, the project investment is the least. According to the project duration and quality, we will comprehensively consider the impact of the production and transportation efficiency of CRTSII slab, and make overall arrangements, and calculate the production scale, supply distance and planned supply time of the slab in detail.

4.3. Divide function areas

In general, the functions of temporary facilities tend to be relatively monotonous, usually include production and life. For slab plant, mainly according to production process flow of CRTSII, which is subdivided into production zone, steel zone, concrete mixing zone, assembly zone, storage zone, auxiliary zone, and office & living zone.

4.4. Calculate lean scale of function areas

Scientifically determining the lean scale of all function areas is the core of the lean design in the planning layout of slab plant. Production zone size is related to demand of CRTSII slab, construction period and operation space, etc. Steel zone size, concrete mixing zone size and assembly zone size are related to production cycle and capacity. Storage zone size is related to the production scale, inventory strategy, inventory turnover level, product production cycle, etc. Office & living zone size shall be calculated according to the number of employees and the nature. While auxiliary zone size is determined by the actual situation on site.

4.5. Construct lean layout planning

Lean layout planning refers to the use of lean production, system engineering and other knowledge, with the help of design technology and means, theoretically determines the layout planning to meet the requirements of lean thinking. According to the literature summary, CRTSII slab plant layout have Z-type, T-type, separation arrangement and double line layout. In general, the new slab plant layout can be revised on the basis of four types. The four types are compared as follows:

| Types      | Characteristics                                      | Application           |
|------------|------------------------------------------------------|-----------------------|
| Z-type     | Production zone, steel zone, assembly zone are connected into Z type | Rectangular space     |
| T-type     | Production zone, steel zone, assembly zone are connected into T type | Square space          |
| Separation | Assembly zone is constructed separately               | Big space             |
| Double line| Assembly zone is constructed separately, but need 2 sets of equipment | Big space and tight duration |

4.6. Evaluation lean solution

Evaluation includes qualitative evaluation and quantitative evaluation. There are many qualitative evaluation methods, such as fuzzy evaluation method, hierarchy analytic process, expert scoring method, etc. The quantitative evaluation method mainly refers to the simulation method. Through the visual environment, simulation method can effectively analyze the logistics cost, operation efficiency, equipment utilization ratio and other index data of each layout scheme, and use various optimization evaluation algorithms to make scientific decisions of lean layout design.
4.7. Analyze the waste
The traditional waste analysis refers to the seven waste analysis of the factory, includes excessive waste of manufacturing, waste of waiting, waste of handling, waste of processing, waste of inventory, waste of action and waste of poor production. Lean design in the planning layout of slab plant mainly includes the waste of handling and waste of inventory. Simply, we can attribute these two types of waste to cost waste, namely the land acquisition costs (proportional to size) and transportation cost (closely related to the transportation distance), so the waste analysis of this article is refers to the analysis of the two cost waste.

4.8. Analyze reversibility
Reversibility analysis is a very important aspect of distinguishing temporary facility layout planning from other facilities. With the end of the project, temporary facilities are usually handled in two ways: (1) If the site is suitable, it can be transformed into permanent facilities, such as station or factory; (2) Restoration to usable reclamation land. For the second way, at the beginning of layout planning, we should fully consider the location and arable land to minimize the cost of reclamation.

4.9. Complete lean planning
After the above problems are solved, according to the corresponding discriminant criteria, the decision makers choose a relatively optimized lean layout planning of slab plant. The different requirements of the project lead to different indexes and weights of indexes. For temporary facilities (such as slab plant), the final layout planning is not decided by the contractor, but decided by the lean design team after comprehensive evaluation and consideration, the contractor just carries out the final layout planning.

5. Example of lean design in the planning layout of slab plant --Changqing plant
According to the process of lean design in the planning layout of slab plant, this article combines with the characteristics of slab plant layout planning, applies relevant theories and methods of modern facility planning, gets a feasible and effective layout plan of changqing plant, as shown in figure 2.

![Figure 2. A feasible and effective layout plan of changqing plant.](image)

Compared with the original layout of changqing plant and figure 2, the two layout schemes are comprehensively evaluated from the aspects of logistics efficiency, handling efficiency, site utilization rate and management service.

| Item               | The original layout                                      | The lean layout                                      |
|--------------------|----------------------------------------------------------|------------------------------------------------------|
| Logistics efficiency | Gate1 only, longer handling distance for slabs when they are transported out. | Gate2 is set at the upper left of the slab plant, the transportation distance is significantly shortened 53.33%. |
| Handling efficiency | As the function areas of the two schemes has not changed, the handling efficiency in the plant is similar. |                                                |
| Utilization rate   | The total area of the slab plant is 121 mu.              | Saving about 4.5 mu of land area.                    |

Table 3. Comparison of two layout schemes.
6. Conclusion

As a necessary temporary facility for railway construction, the slab plant plays a powerful role in promoting the entire railway construction project. In this article, lean thinking is introduced into the layout planning of CRTSII slab plant, and a lean design framework suitable for the planning layout of slab plant is proposed. Aiming at the lean layout planning, the lean thinking is implemented in every step of the design. Finally, this article takes changqing plant of Beijing-Shanghai high-speed railway as an example, and verifies that the lean design method can achieve the goal of the lean layout in the slab plant. The result can provide reference and guidance for the layout design of temporary facilities in China.

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