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Layout Design-Based Research on Optimization and Assessment Method for Shipbuilding Workshop

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Abstract: The research study proposes to examine a three-dimensional visualization program, emphasizing on improving genetic algorithms through the optimization of a layout design-based standard and discrete shipbuilding workshop. By utilizing a steel processing workshop as an example, the principle of minimum logistic costs will be implemented to obtain an ideological equipment layout, and a mathematical model. The objectiveness is to minimize the total necessary distance traveled between machines. An improved control operator is implemented to improve the iterative efficiency of the genetic algorithm, and yield relevant parameters. The Computer Aided Tri-Dimensional Interface Application (CATIA) software is applied to establish the manufacturing resource base and parametric model of the steel processing workshop. Based on the results of optimized planar logistics, a visual parametric model of the steel processing workshop is constructed, and qualitative and quantitative adjustments then are applied to the model. The method for evaluating the results of the layout is subsequently established through the utilization of AHP. In order to provide a mode of reference to the optimization and layout of the digitalized production workshop, the optimized discrete production workshop will possess a certain level of practical significance.

Keywords: visual parametric model; steel processing workshop; layout optimization design; improved genetic algorithm; assessment methods; optimization algorithm; shipbuilding workshop
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1 Introduction

In recent years, digitalized ship manufacturing technology has been widely applied in the field of ship construction. Thus, the use of computers in improving the operating efficiency of shipbuilding enterprises has formed a new research direction in the industry.

For shipbuilding enterprises, the production process is essentially a process of "material flow", and ships are the final results of this flow and combination of materials (Chen *et al*., 2002). As a core technology of rapid ship construction, Business Process Re-engineering (BPR) plays a crucial role in improving shipbuilding efficiency. In recent years, the shipbuilding enterprises in Japan and Korea have greatly improved their production efficiency through specialized production of intermediate products and solidified production process(Zhong *et al*.,2004). On the other hand, the shipbuilding industry in China has fallen behind in terms of production process management. Due to the prevalent emphasis placed upon production rather than logistics, Chinese shipbuilding enterprises have overlooked the need of rational organization for production logistics in shipbuilding workshops. Therefore, unreasonable layout of equipment in the production process has resulted in excessive logistics and low efficiency in ship construction. As a typical discrete manufacturing industry, the shipbuilding industry is characterized by small batch size, unfixed product types, and changeable quantity, all of which pose considerable difficulty for layout optimization. Since steel processing is a key step in the shipbuilding process, the production efficiency and quality of steel processing will have significant effects on the quality of ship products, the production costs, and the production cycle. An optimized design for the layout of the steel processing workshop will help reduce costs by raising work efficiency, minimizing energy consumption, reducing the floor space, and acquiring maximum output efficiency within a limited area.

The main issue of workshop's layout is the manufacturing process or logistics requirements. Meanwhile layout problem performs multiplicity for different optimization objectives, practical problems and layout design stages. By now, there are few achievements in workshop layout research field. They are mainly the study targeted at workshop scheduling model and the optimization study targeted at the application of various optimization algorithms for workshop layout programs. For example, Dr. Guanghua Hu at Huazhong University of Science and Technology took the intelligent optimization algorithm to solve the operable and integrated workshop layout problems, and developed the desktop-type visual layout design prototype system (Hu *et al*., 2007). The design of workshop layout makes slow progress in 3D modeling and visualization, and individual study establishes equipment layout demonstration model on the basis of optimization. There are few studies targeted at shipbuilding steel material processing workshops, and no study case targeted at 3D

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digital layout optimization of this type of workshop. For example, Professor Yujun Liu at Dalian University of Technology established the OOCPN-based steel material workshop scheduling system model, and extended the study targeted at the planning design of flexible automated steel material processing workshop (Liu *et al*., 2008).

Using a certain shipyard's steel processing workshop as an example, this article aims to obtain optimized characteristics through the use of genetic algorithms. Adopt the PMX crossover algorithm to replace traditional crossover algorithms, and adopt the Boltzmann ratio change technology to control the selection rate, thereby improving the optimizing efficiency under the premise of ensuring the optimizing results. Make a comparison to the production efficiency of a certain shipyard steel material processing workshop layout before and after the optimization according to the digital workshop layout optimization scheme established in this paper, to prove the feasibility and validity. The evaluation system of workshop layout established in this paper fully considers the human factors engineering, and takes the workshop layout as a comprehensive system covering people, machine and environmental factor to consider.

With the visualization capabilities of the CATIA software, a reference method and approach can then be obtained through the study of the digitized workshop layout optimization. And the 3D visual prefabricated model can be put forward to establish to solve the problem of slow model updating speed.

2 Digitized workshop layout optimization project

Using surveys and questionnaires to understand the production process of workshops in the industry, a rational optimization method can be established as the standard production process under a guaranteed "soft" condition. The production goals of each workshop can be established in accordance with the production goals of the enterprise. After assessing the capacity of each machine, optimization is executed for existing resources (ERP) in order to find key factors in the production. Needed equipment can then be supplemented and redundant equipment reduced accordingly. On this basis, the three-dimensional software can be used to create a digitized workshop model, including a manufacturing resource model, division of the manufacturing units, and a technology and process model, so that a visual parametric model of the digitized workshop can be established. In order to determine the final optimal solution, an optimization algorithm is used to optimize the initial layout of the workshop with a variety of boundary conditions taken into account. An evaluation of the optimal project will subsequently be made through the use of digitized software or its developmental function. If the necessary requirements are not met, the boundary conditions can be changed and other optimal solution can be chosen in order to obtain the best optimal project. The process is illustrated in Fig 1.

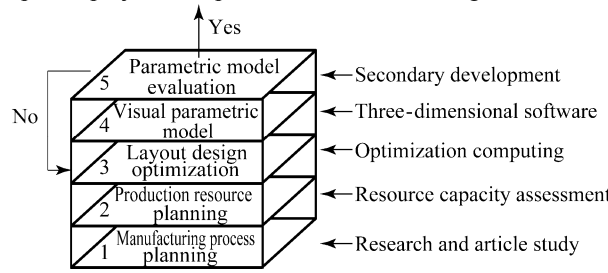

Fig.1 Optimal solution to the digitized workshop layout design

2.1 Production process and resource optimization

The steel processing workshop has the main functions of processing raw steel plates into assembly parts for the hull. The main technologies are used for the pretreatment, cutting, edge treatment, cold processing, and heat processing of steel plates. Steel processing workshops generally produce four types of parts: flat piece, flanged edge piece, 1st curved piece, and 2nd curved piece. Take the steel processing workshop of a certain shipbuilding enterprise as an example, its processing capability is designed to process 2000 tons (approximately 500 to 600 steel plates) every shift (8 hours). The main processing equipment in the workshop includes the steel plate pretreatment production line, CNC plasma cutting machine, gantry cutting machine, photoelectric cutting machine, CNC milling machine, edge planing machine, plate bending machine, rolling machine, hydraulic machine, and line-heating equipment. The production process is shown in Fig 2. The arrows indicate the processing order, direction of material flow, equipment type, and types of the part produced. The workshop contains a variety of processing equipments and technical parameters, as shown in Table 1. The workshop equipment layout is as shown in Fig.3, totally in three spans, each span is 130 meters long and 16 meters wide, while the factory building of is meters long and 52 meters wide. The same type of equipment layout is relatively concentrated, which makes the frequency of material lateral movement and reciprocation in the production process bigger and increases the production cycle and costs. The processing capacity of steel workshop can not meet the design requirements due to unreasonable machine number and model allocation, the steel plates number in each batch of processing is less than 400 pieces, or about 2/3 of the designed production capacity, and often brings unsmooth circumstances in the material circulation. And Fig. 4 shows the workshop equipment utilization rate.

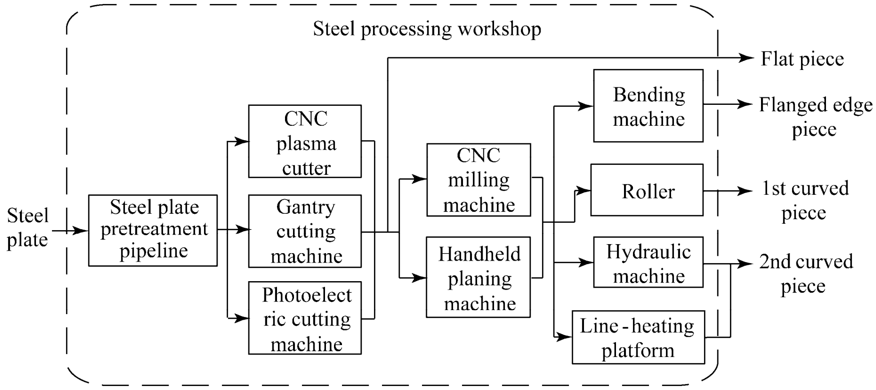

Fig.2 Steel process logistic diagram

Table 1 Parameters of the equipment in the steel processing workshop

Equipment name	Quantity	Dimensions(L×W ×H) /mm	Work dimensions (L ×W×H) / mm	Processing capacity (T/ shift)	Gap (T/ shift)
Steel plate pretreatment pipeline 1	1	30000×5000×4000	32000×7000×4000	800	0
Steel plate pretreatment pipeline 2	1	50000×5000×4000	52000×7000×4000	1200	0
CNC plasma cutting machine	1	40000×6000×2000	42000×8000×2000	600	600
Photoelectric cutting machine	1	45000×5000×2000	47000×7000×2000	400	0
Gantry cutting machine	1	50000×6000×3000	52000×8000×3000	400	0
CNC milling machine	1	15000×10000×3000	15000×15000×3000	170	0
Handheld planing machine	3	500×500×400	12000×10000×2000	125×3	−45
Hydraulic machine 1	1	3000×3500×2800	6000×6500×2800	300	300
Hydraulic machine 2	1	6400×1800×5560	10000×4800×5560	400	0
Bending machine	1	2000×1600×3000	8000×5000×3000	200	0
Roller	2	10520×2580×2120	12000×7000×2120	250×2	250
Line-heating platform	1	1000×1000×100	5000×5000×2000	7	30

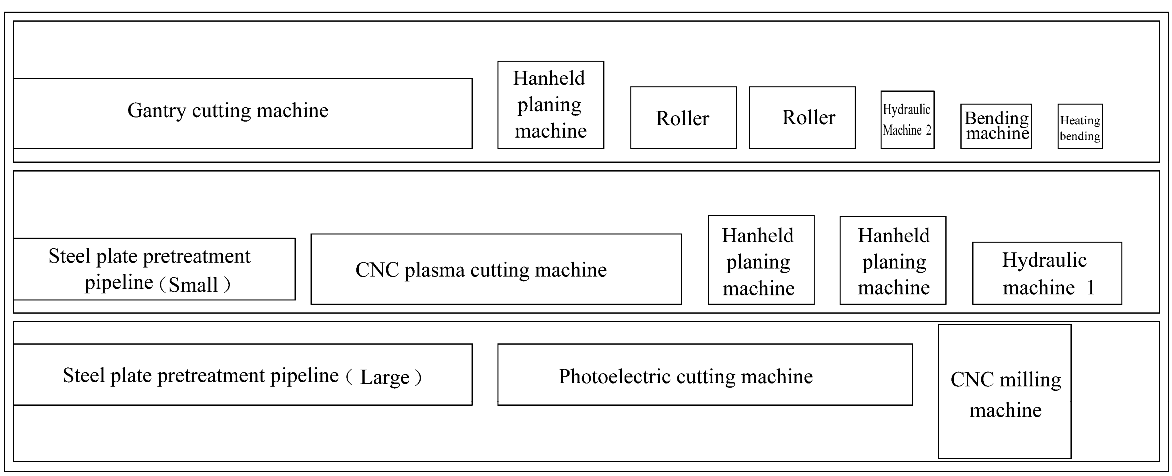

Fig.3 Two-dimensional workshop layout (The original)

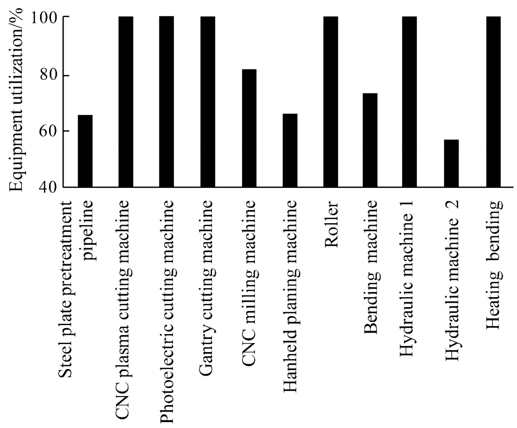

Fig.4 Equipment utilization

Table 2 Percentage of allocated labor

Work/ Equipment	Motorized vessel		Non-motorized inland waterway vessel
	Ocean	Inland waterway	
Cutting	26	20	23
Edge processing	6	5	6
Bending, Roller	14	11	13
Hydraulic machine (Cold press)	13	17	17
Line-heating platform	9	18	13
Steel plate pretreatment	32	29	28

According to statistics, the ratio between the flat piece, hem piece, 1st curved piece, and 2nd curved piece produced in the steel processing workshop is 5:1:3:1, respectively. Based on this ratio, the processing capability of equipment in Table 1 and the ratio between various labors in Table 2, from the load balancing analysis of existing equipment in the workshop we can calculate the processing capacity gap between the shifts for each technology in the workshop, as shown in the last column of Table 1. It can be observed that this design obviously cannot achieve the designated production capacity of the workshop. Clear inadequacy exists in the number of CNC plasma cutting equipments and cold bending equipments, with apparent tension in line-heating stations. However, a slight proficiency is present in edge-processing equipment. After adjustments are made in the equipment configuration by adding 1 CNC plasma cutter, 1 hydraulic machine, 1 roller, and 4 line-heating platforms (without considering the objective conditions such as equipment price and site constraints), a basic match among the processing capability of each machine will be established, and the workshop requirements will be met.

2.2 Determining the workshop layout model

Fixed layout, product layout, technology layout and group layout are the four basic forms of equipment layout (Maotao Zhou *et al*., 2009)), among which the fixed layout is generally used for large-scale processing objects that are difficult to move, and is therefore not suitable for a steel processing workshop. The other three layouts are determined according to the number of parts and types of parts processed per unit time. Their relationships are shown in Fig 5. The type number of parts produced in the steel processing workshop ranges from 10 to 100, and the number of the parts produced per hour is within 100. Accordingly, the group layout is considered to be a more reasonable choice. The guiding ideology behind group layout is to group parts with similar technological requirements into one part family. Each part family dictates how related equipment is arranged in order to form a manufacturing unit. The group layout workshop mode can transport the materials of the same manufacturing process and transportation, as well as save transportation costs and manufacturing cycles.

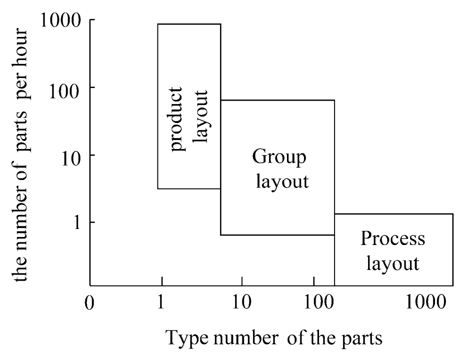

Fig. 5 Relationship between layout and processing object

2.3 Determine Workshop Occupied Area

The overall layout area of the work shop will be utilized for equipment and work, which include necessary buffer zones, storage space, and paths with both sidewalks and transport roads. Total area of the workshop can be determined by using formula (1) to calculate:

$$A_t = A_e + A_y + A_b + A_r + A_o \quad (1)$$

where A_t is the hetotal workshop area, A_e the equipment and work area, A_y storage area, A_b buffer zone, A_r path area, and A_o represents truss, auxiliary equipment, office area, *etc*.

2.4 Planning of the operating area

According to its layout model and technological characteristics, the steel processing workshop is divided into three manufacturing units: the steel plate treatment unit, the cutting unit, and the forming unit. Based on equipment quantity and work area, these processing units are arranged from left to right as the steel plate processing unit (including 2 pretreatment pipelines), the cutting unit (including 4 cutting machine, 1 CNC milling machine, and 3 handheld edge planers), and finally the forming unit (including 1 bending machine, 3 hydraulic machines, 3 rollers, and 5 line-heating stations).

3 Layout optimization through improved genetic algorithm

The main goal of an optimized layout design is to upgrade the various layouts of a workshop in order to yield a reasonable logistic flow, and establish the shortest overall transportation route, and the minimum transportation costs, while the current technological standards are maintained (Du *et al*., 2009). The process for material traveling transportation is: hoisting → translation to the next station or sideway to a trolley → putting down. Different device layouts have a great influence on material transport distances, when the logistics quantity is reduced, the transport distance shall be decreased and the transport costs shall be reduced accordingly. Transportation cost is believed to be proportional to the size of the logistic flow. When the production goal is fixed and the material movement amount is a constant, the transportation distance is considered to be optimal, and the transportation cost is also optimal. Therefore, this paper does not separately optimize the transportation costs.

3.1 Establishment of a mathematical model

Multi-row machine layouts will be made for the equipment in each span. The mathematical model is described as follows:

Let "x_i" and "y_i" represent the distance from the center-line of the machine to the vertical reference line and horizontal reference line respectively. The decision variable "z_{ik}" is as follows:

$$z_{ik} = \begin{cases} 1 & \text{If machine } i \text{ is allocated with } k \\ 0 & \text{Others} \end{cases} \quad (2)$$

Multi-row machine layout within a region is described in the following mixed integer programming problems:

$$\min \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} f_{ij} \left(\left| x_i - x_j \right| + \left| y_i - y_j \right| \right) \quad (3)$$

$$\text{s.t.} \quad \left| x_i - x_j \right| z_{ik} z_{jk} \geq \frac{1}{2}(l_i + l_j) + d_{ij} \qquad i, j = 1, \ldots, n \quad (4)$$

$$y_i = \sum_{k=1}^{m} l_0 (k-1) z_{ik} \qquad i = 1, \ldots, n \quad (5)$$

$$\sum_{k=1}^{m} z_{ik} = 1 \qquad i = 1, \ldots, n \quad (6)$$

$$\sum_{i=1}^{n} z_{ik} \leq n \qquad k = 1, \ldots, m \quad (7)$$

$$x_i, y_i \geq 0 \qquad i = 1, \ldots, n$$

$$z_{ik} = 0,1 \qquad i = 1, \ldots, n, k = 1, \ldots, m$$

where n is the quantity of machines, m the number of rows, f_{ij} frequency of visit between machine i and machine j, l_i length of machine i, l_0 distance between the two adjacent center lines, d_{ij} minimum distance between machine i and machine j, x_i distance between the center line of machine i and the vertical reference line l_V, y_i distance between the center line of machine i and the horizontal reference line l_H.

The objective of this mathematical model is to minimize the number of necessary visits between equipments. Constraint Eq. (4) ensures that no machines are overlapping, and constraint Eq (5) to Eq (7) ensure that only one machine is allocated in a row. Reference lines and parameters are shown in Fig 6.

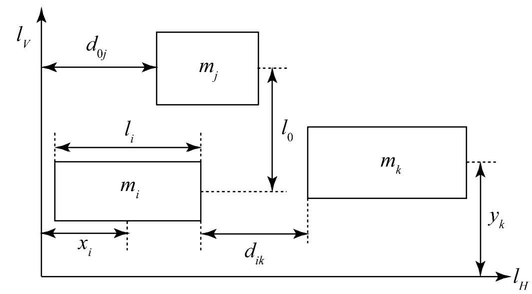

Fig.6 Schematic of parameters and reference lines

Based on this model, it can be seen that in order to solve the problem, the following tasks must be completed:

1) Allocation of equipment to a specific row (designated with the y-coordinate);

2) Determining the best position within each row (designated with the x-coordinate).

After we've determined the equipment layout, arranging buffer and channel according to need makes it easy to identify the final workshop covering area and layout.

3.2 Improved Genetic Algorithm

Genetic Algorithm provides a general framework for solving complicated system optimization problems. Genetic algorithm is a calculation model that simulates the biological evolution process of Darwinian natural selection and the mechanisms of genetics for the purpose of searching for an optimal solution through the natural evolutionary process. This paper chooses the genetic algorithm to solve the optimization problems on the workshop equipment layout.

In the genetic algorithm, an alternative solution is called a chromosome, each chromosome consists of a number of genes, each gene can be used to represent a number, and a certain number of chromosomes compose a population. Genetic algorithm is one process to conduct iterative computation to alternative solutions, and each iteration is called a generation. After the iteration completion, take advantage of certain evaluation functions to perform performance evaluation to the current population, and generate a new generation based on the evaluation generation, making population capacity fixed as a constant. The initial population is randomly determined. And the above iterative computation process shall be ended until finding a satisfactory solution or reaching a pre-determined iteration number.

The evaluation function in the algorithm is mainly used for evaluating each chromosome in the current generation, removing a certain number of low-performance chromosome in the next generation through the evaluation, retaining some high-performance chromosomes, complementing some new chromosomes through genetic operators, to ensure the next generation population to contain new information, make its average performance constantly improved, finally obtain very good populations, and meet the requirements in solving problem.

In the genetic process, select a certain number of the most outstanding chromosomes in the current generation as parents of the reproduced offspring to form a mating pool, and produce some new chromosomes through genetic operators to form the next generation of chromosome population. Usually genetic operators cover two types, i.e. crossover and mutation, and crossover shows the random process of using excellent chromosomes to conduct hybridization to produce new individuals. And the mutation simulates accidental gene mutation phenomena in the biological evolution process. In order to improve the efficiency of the search, the author has made improvements to the algorithm. Adopt the PMX crossover algorithm to replace traditional crossover algorithms, and adopt the Boltzmann ratio change technology to control the selection rate, thereby improving the optimizing efficiency under the premise of ensuring the optimizing results.

3.3 Initialization

Since issues studied in this article involve multi-row equipment layouts, a real-number encoding method consisting of break marks and equipment order is selected. A chromosome represents an equipment layout project, and a gene represents a machine. What we are considering here is not the equipment shape dimension, but the equipment working dimension. Each chromosome is composed of two parts, the break marks and equipment order, which are expressed as follows:

$$\{(r_1, r_2, \ldots\ldots, r_{k-1}), (n_1, n_2, \ldots\ldots, n_m)\}$$

among which, $(r_1, r_2, \ldots\ldots, r_{k-1})$ serves as the break marks, and $(n_1, n_2, \ldots\ldots, n_m)$ serves as the order of the equipment. For example, if the break marks are (5, 6, 7), the indicated machine tools are divided into four arranged rows. Machine tools n_1 to n_5 are in row one, machine tool n_6 to n_{11} are in row two, machine tools n_{12} to n_{18} are in row three, and the remaining machine tools are placed in row four. Break mark values are determined in accordance with actual situations, and may be included in the breeding operation if needed. In the case of transforming an old workshop, if the numbers of machine tools in each line have been verified, they cannot be included in the breeding operation. For new workshops, however, break marks should be included in the breeding operation.

Apply natural encoding to the equipment in our example of the steel processing workshop, as shown in Table 3. A randomized method is used to generate the initial species. The chromosomes include: separators and equipment order.

Table 3 Genetic code of equipment

Equipment	Code	Equipment	Code
Steel plate pretreatment pipeline 1	1	Hydraulic machine 1-2	12
Steel plate pretreatment pipeline 2	2	Hydraulic machine 2	13
CNC plasma cutter 1-1	3	Roller 1-1	14
CNC plasma cutter 1-2	4	Roller 1-2	15
Photoelectric cutting machine	5	Roller 1-3	16
Gantry cutting machine	6	Bending machine	17
CNC milling machine	7	Line-heating platform 1-1	18
Handheld edge planer 1-1	8	Line-heating platform 1-2	19
Handheld edge planer 1-2	9	Line-heating platform 1-3	20
Handheld edge planer 1-3	10	Line-heating platform 1-4	21
Hydraulic machine 1-1	11	Line-heating platform 1-5	22

3.4 Operator Selection

Commonly used strategy selections include the fitness ratio method, best individual saving method, expected value method, ranking selection method, and the league selection method. In this article, the ranking selection method was selected for utilization. Establish an adaptive function, obtain the adaptive function value for all chromosomes in the population, and take the *a* sequence. Through the comparative method, the transverse adaptive function value can be obtained, and the maximum value corresponding to the sequence will be added into a new population of chromosomes. With this method, once enough sequences have been filtered out to compose a new population, original sequences in the population with poor adaptability will be discarded in order to improve quality and individual survivability. Formula (8) is based on the selected adaptive function.

$$F(w) = \theta_1 f_1 + \theta_2 f_2 \tag{8}$$

where f_1 is the Distribution function for the allocation of equipment, f_2 the Distribution function for the allocation of equipment within a row, θ_1 Weight distribution function for the allocation of equipment, θ_2 Weight distribution function for the allocation of equipment within a row.

Since horizontal transport is much easier than row-crossing transport (transport that involves crossing a row) for the logistic flow in a steel processing workshop, row-crossing movements should thus be minimized. In the selection of weights, the rule of thumb is to set θ_1=0.6, and θ_2=0.4, which are the most ideal values.

3.5 Mutation

Common mutation operators cover inversion, insertion, translocation, swap, etc. In this paper choosing exchange operator, means to exchange two genes from selected location, so as not to fall into local optimal solution, as shown in Fig. 7. The mutation rate is defined as the percentage of mutant gene number in the total gene number in the population. The mutation rate controls the proportion of import populations of new genes. If the mutation rate is too low, some useful genes cannot enter for choice; if too high, random changes shall be too much, then the offspring may lose to inherit good characteristics from the parents, so this algorithm will lose the learning capability from the past search. And the mutation rate in the case shall take 0.4.

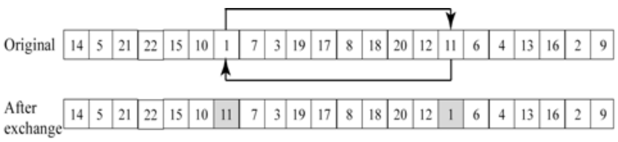

Fig.7 Mutation operator

3.6 Crossover

Crossover operator then achieves gene swap between two random chromosomes within a corresponding gene segment, thereby obtaining new chromosomes and improving individual diversity of the new population. The basic element of a crossover is composed of two parts: A randomized method to determine the separator, and the PMX method to process the order of equipment.

A new separator is formed in two steps:

1) Determining the upper and lower bounds of a separator;

2) Randomized selection of an integer from the range between the upper and lower bounds.

The upper and lower bounds of a separator can be calculated directly through:

$$s_U = \max\{s^1, s^2\} \tag{9}$$

$$s_L = \min\{s^1, s^2\} \tag{10}$$

"s_U" and "s_L" are subsequently used to construct a closed interval [s_L, s_U]. The new separator is an integer randomly selected within the range. The PMX crossover algorithm will generate a new order for the equipment:

Two points are then selected from the balanced randomized sequence above to define a substring called the mapping segment;

1) Exchange the two substrings of the parents to produce an original offspring;

2) Determine the mapping relationship between two mapping segments;

3) Legalize the offspring in accordance with the mapping relationship.

This procedure is illustrated in Fig. 8. Crossover rate is defined as the ratio between the offspring number under crossover generation in each generation and the population individual number. High crossover rate can reach larger solution space, thereby reducing the chance of stopping at non-optimal solutions; but if the ratio is too high, it will consume a large amount of computing time due to searching unnecessary solution space. And the crossover rate in this case shall take 0.75.

Fig.8 Crossover by PMX

3.7 Algorithm and Control Selection

The control issue with rate selection can be better solved with the Boltzmann variable ratio technique. The initial temperature will be set higher to ensure the preservation of global optimal solution. The temperature will be decreased gradually in order to set the selected control rate within a reasonable reduction range. The processing speed will be set in an accepted range relative to the complexity of the product. With a population size of 100, the maximum of genetic algebra of 250, initial temperature will be set at 35 or higher, minimum temperature at around 1, and decreasing rate 0.15, crossover rate 0.75, mutation rate 0.4. The program will iterate through 180 generations until an optimal solution is found, and an adaptive value of 1.40015×10^{-05} is obtained. The evolution process is illustrated in Fig 9.

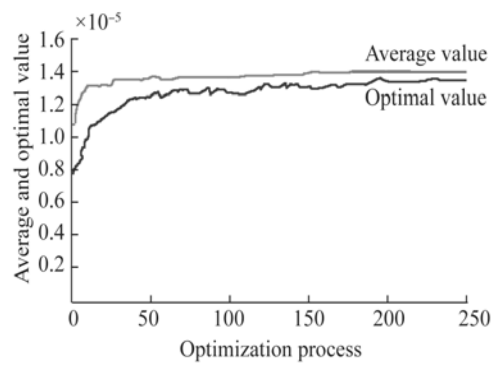

Fig. 9 The evolution process

If the span number (line number) is 3, the span (line width) is 16m, each span will have a length of 150m (line length), we can get the optimal solution:

$$\{(9,6),(1,3,7,13,14,11,18,19,20,6,5,8,15,17,21,2,4,9,10,16,12,22)\}$$

Equipment layout is shown in Fig. 10.

If the span number (line number) is 4, the span (line width) is 16m, each span will have a length of 120m (line length), we can get the optimal solution:

$$\{(8,6,4),(3,8,9,14,11,18,19,20,1,5,12,17,21,22,6,7,13,15,2,4,10,16)\}$$

Equipment layout is shown in Fig 11.

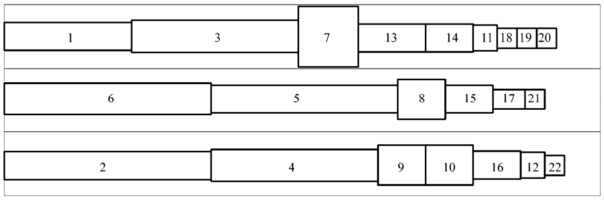

Fig.10 Sketch map of the layout

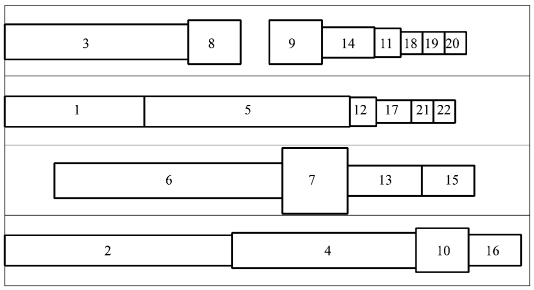

Fig.11 Sketch map of the layout

3.8 Optimization evaluation results

In this case, the Analytic Hierarchy Process (AHP) was applied to evaluate two optimal solutions obtained from the optimization algorithm. The assessment objectives include the three aspects of the layout of the economy, advanced, and humanized. Factors weighted in this case are shown in Table 4. Via many experts' scoring, the solution 1 is 87.12 and the solution 2 is 81.62 after weighted average. Obviously the solution 1 is better than the solution 2. Fig. 12 shows the interface of the assessment program.

Table 4 Factor weights in the Analytical Hierarchy Process of the workshop

Evaluation factor		Weights
The first level	The second stage	
Economy	Occupied surface area	0.12
	Space utilization	0.202
	Equipment costs	0.01
Advanced	Minimum amount of material movement	0.252
	forms of equipment layout	0.047
	Flexible Manufacturing(FM)	0.142
	Relationship between pathways and layout	0.011
	Logistics span	0.145
	Other workshop logistic coordination	0.008
Humanized	Security	0.012
	Environmental Protection	0.011
	Working comfort	0.04

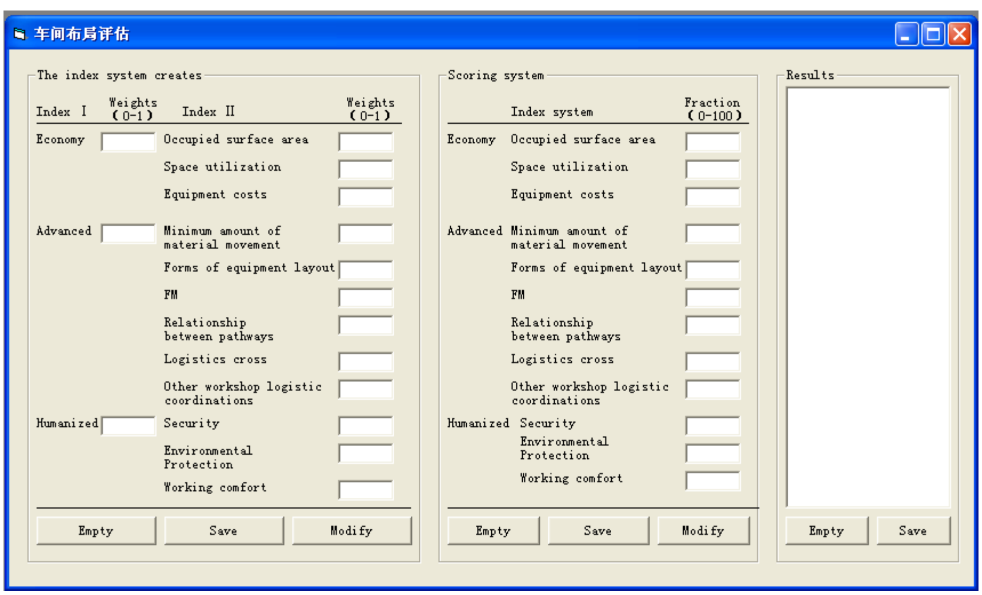

Fig.12 Interface of the assessment program

3.9 Optimal solution for workshop layout

Based on evaluation results, the solution 1 has been determined for the reference layout. Manually insert walkways, and make appropriate adjustments, and the final layout is as follows. For the layout of the ship manufacturing workshop, each span will have a width of 16 m, span-spacing distance of 1m, each span will have a length of 150 m, and a workshop thickness of 1m for a total width of 86m for a total length of 152 m. The total workshop area will be 13,072 m^2. This layout will meet the various requirements of the generator for production, such as water, electricity, steam and air supply capacities as well as air-conditioning, heating, ventilation and lifting equipment's load capacities. In accordance with equipment dimensions and processing work area, the steel plate pretreatment unit will utilize an area of 1,344 m^2, cutting unit will utilize an area of 2,944 m^2, the forming unit with an area of 6,084 m^2. The span design has an area of 2,400 m^2, and a length-width dimension of 150m-16m respectively. After optimization, the workshop length was increased by 20 meters, the area was increased by 960 square meters and the production capacity was increased by 1/3, thereby reaching the designed production capacity of 2,000 tons for each batch of steel plate processing, and achieving quite balanced equipment utilization rate by getting close to 100%. The optimized workshop layout plan is shown in Fig 13.

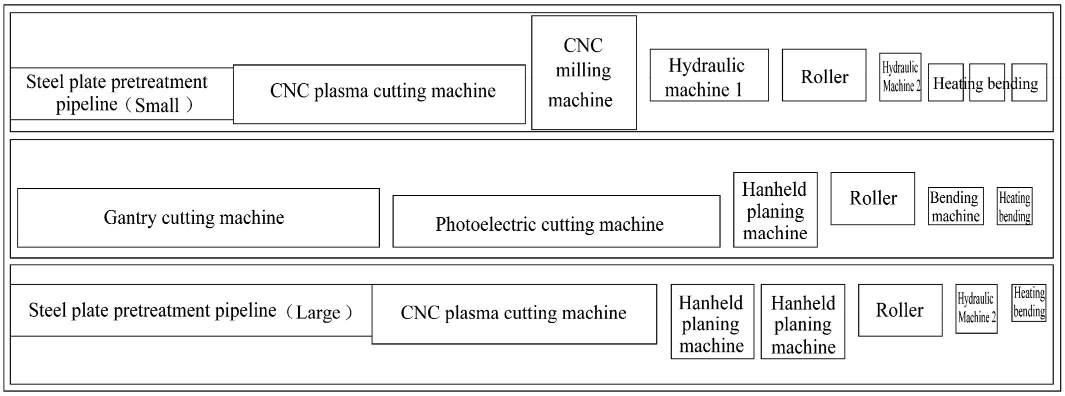

Fig.13 Layout plan for the steel processing workshop

4 Establishing a visual parametric model of the steel processing workshop

The workshop visualization parameter model is established by CATIA Software. CATIA is the English abbreviation of Computer Aided Tri-Dimensional Interface Application and the CAD/CAE/CAM integrated software of France Dassault System (DS) Company, takes the lead in the world CAD/CAE/CAM field, and is widely used in aerospace, automobile manufacturing, shipbuilding, machinery manufacturing, electronics, electrical appliances and consumer goods industry; and its integrated solutions cover all fields of product design and manufacturing (Wu Zheng and Wang, 2005). The 3D plant designing module of the CATIA software is an object-oriented independent system. It enables designers to easily create a manufacturing-type design or various other types of designs, including plant, work area, cable, pipeline, road design, etc. Its representation and validation capabilities provide factory designing with high-efficiency methodology. The entire designing process can also be extended and/or modified in order to make the design more perfect. The enclosed virtual workshop environments in the open database provide users with multiple logical and physical design information, from which a digitized 3D model of the workshop can be created easily and efficiently.

Compared with other 3D software, CATIA has a friendly interface, quick modeling modes, good compatibility and exploitability. Concerning another important reason, in the follow-up research subject, the workshop dynamic simulation, human factors engineering design, reverse engineering, etc. can be collaboratively solved through CATIA software, thereby reducing the model transformation problem and improving the efficiency and accuracy.

4.1 Construction of the resource parametric model

The 3D plant design module of CATIA comprises three parts: the factory design, the layout of production operation areas, the layout of equipment and auxiliary facilities within the operation areas. The CATIA software can also be used to establish a proportional three-dimensional model of various manufacturing resources. Some of the equipment models are shown in Fig. 14. The module can preserve and classify the manufacturing resources of the model, its associated properties, and its constraint properties. In combination with the DMU module and the ergonomic module, a simulation model of a man-machine interaction system can also be created to observe the interaction between man and machine, the virtual operation processes, and so on.

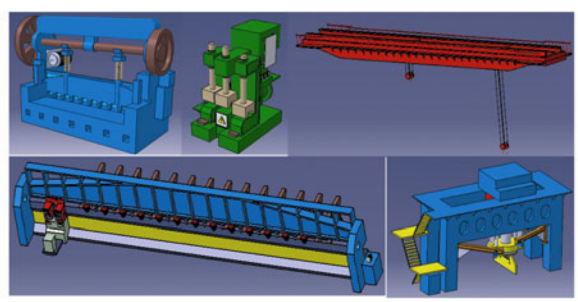

Fig.14 Established resource parametric model

4.2 Visual parametric model of the steel processing workshop

A fast layout of the 3D workshop model can be acquired by means of establishing a prefabricated manufacturing resource model in various production areas, which can rapidly allocate positions for equipment. Generally, the dimensions are set at the maximum contour value of the equipment. The prefabricated workshop model offers convenience with previews of the three-dimensional model, quick modifications, and interference checks. The effects of the prefabricated steel processing workshop model can be seen in Fig 15.

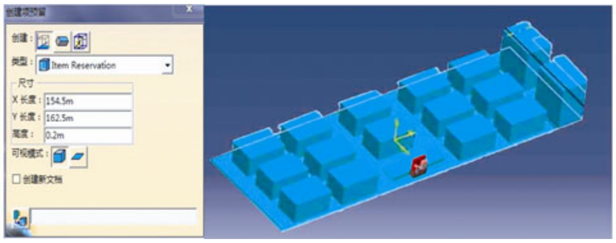

Fig.15 Effects of prefabricated equipment

Parameters such as road width and positioning can all be set within the model in order to complete the layout of pathways. After interference checks, the corresponding equipment models from the construction and manufacturing database can be imported into the prefabricated model. A detailed visual parametric model of the steel processing shop can then be observed. The digital workshop model parameters are shown in Fig. 16. First, this plan establishes the production range of each span in correspondence with the cutting process flow of the workshop, and possesses the necessary assembly line capability. At the same time, the vertical and horizontal contacts were increased in order to make material management more convenient.

Fig.16 Screenshot of the visual parametric steel processing workshop model

When workshop layout is deemed satisfactory, it can be added to the technical drawings directly to indicate the size and layout of equipment. More engineering drawings can also be outputted by specifying specific layout designs, as shown in Fig 17.

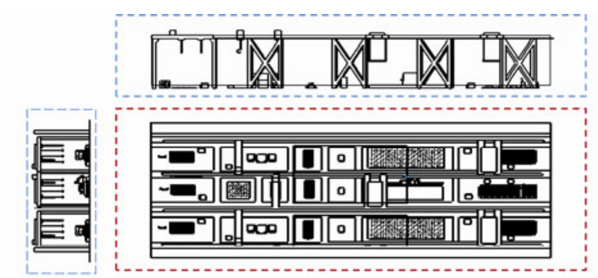

Fig.17 Technical drawing of the steel processing workshop

5 Conclusions

1) For the sample steel processing workshop, the authors put forward the thought of taking the achievement of minimum workshop logistics costs as the principle of equipment layout, as well as the digital workshop layout design solutions, which are based under the premise of manufacturing resource planning and production processes optimization, and take algorithm iteration optimization as the means; selecting expert evaluation decision layout optimization scheme, and presenting the simulation workshop layout of 3D visualization software.

2) The mathematical model was established, which took the total distance of minimizing equipment room for necessary visits as the target. This article has made improvements in the traditional genetic algorithm in order to accelerate convergence speed, and obtained the global optimal solution. The PMX crossover algorithm is adopted to replace traditional crossover algorithms, and the Boltzmann ratio change technology is employed to control the selection rate, thereby improving the optimizing efficiency under the premise of ensuring the optimizing results. Taking a steel processing workshop as an example, in accordance with the planned workshop production target, the workshop optimized layout program is put forward by respectively taking the three-span and four-span layout modes. Then with a population size of 100, genetic algebra maximum of 250, initial temperature will be set at 35 or higher, minimum temperature at around 1, and a decreasing rate 0.15, a crossover rate 0.75, mutation rate 0.4. The program will iterate through 180 generations until an optimal solution is found, and then an adaptive value of 1. 40015e -05 is obtained. The methods adopted by this paper are accompanied by less manual intervention, so the optimization results are credible and can facilitate the quick obtaining of optimal layout programs.

3) This article makes a comprehensive research of the man-machine relationship in the manufacturing workshop system, determines the layout model evaluation target of shipbuilding steel processing workshop as well as the workshop evaluation system. The industry experts are invited for evaluation, then factor weights are obtained to develop evaluation procedures, which are applied to conduct an evaluation on the workshop layout optimization results in this case. So it belongs to the scheme decision and method research on workshop layout.

4) Determining the method to rapidly establish the workshop visual 3D model. Based on the CATIA 3D plant simulation and electronic prototyping module, the 3D equipment model library and the attribute base are established. Proposing the concept of workshop prefabricated model, which uses the maximum 3D rectangular block of the equipment to replace complicating an equipment model to participate in the workshop layout, so as to achieve the objective of fast browsing and modification. And after the completion, the prefabricated model layout shall be upgraded into a refined model layout.

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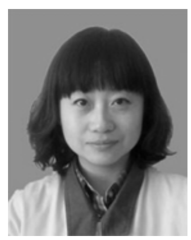

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