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Lean Production Logistics System Applied Research

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Abstract

This paper is aimed to analyze the implementation of the lean production based on the relationship with logistics and to point out that the key of logistics is to support action. Commentary from logistics lean production, to expand the scope of lean production knowledge and the visual field. From the point of view of the application of lean production logistics system function, target, structure and operation management for study, combined with case analysis production logistics system operation process.

Keywords: Lean production , Logistics system , Production logistics , site management, Lean improve

In the past, the research on lean production mainly focused on the application of management thought and method tools, but neglected the special position of logistics system in lean production. The core of lean production reform is logistics, and its relationship with logistics system is closer than any previous production organization, and the objective, structure and function of logistics system have changed obviously.

1.The relationship between lean production and logistics

James. P. Mcwalker believes that lean production pulls production by customer demand, aims at eliminating waste and reacts rapidly in order to make enterprises obtain the best operating efficiency with minimal input and improve the response speed to the market. The core of lean production is simplification, that is, through reducing or eliminating all activities that do not produce value in product development, design, production, management and service, to shorten the response period to customers, and quickly realize the increment of customer value and internal value of enterprises, and increase the return on capital and profit margin. Lean production follows five basic principles: precisely defining product

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value; identifying the value flow of each product; making value flow uninterruptedly; pulling production by customer demand; and always pursuing perfection. [1] [2]

Compared with traditional mass production, lean production has undergone great changes in management theories and methods around the management elements such as people, machinery equipment, materials, methods, environment and so on in the production and manufacturing system. The change of logistics system brought by the transition from pull production to pushing-type production is especially remarkable.

Materials in the production logistics system refer to raw materials, articles being processed, finished products, turnover boxes, auxiliary materials, wastes, and clamping and measuring tools, etc. flowing in the production process. The production and processing nature of manufacturing enterprises determines that material flow is the main control object in the production process, and the logistics system plays a key supporting role in the production process. Lean production logistics is fundamentally different from mass production in terms of system objective, structure, function and operation mode. It also gives new meaning to logistics activities such as storage, transportation, handling, packing, distribution processing, delivery, information processing and so on.

Lean production believes that inventory is "the source of evil" because all kinds of management problems are covered by inventory so that inventory is regarded as an important index to judge the level of lean production. The production site uses "buffer supermarket" to replace the traditional warehouse in order to achieve the goal of "zero inventory". [3] In addition, it adopts Kanban (Japanese) management, one piece-flow cell, synchronization production, SMED, multi-work, and other management techniques to realize the reduction of inventory, shorten production cycle, keep production balanced and continuous, flexibly respond to the changing targets of product quantities and varieties. [4]

In order to reduce the walking and handling waste of the production operators, the equipment is U-type arranged according to the production process to reduce the round-trip time of the workers, and the part presentation equipment next to the production stations is designed according to the principle of action economy to reduce the action waste. In order to achieve rotation production and group machining, parts and components are repackaged, sorted or matched before

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processing. In order to improve the efficiency of direct production workers, the raw materials or parts are sent directly to the production station by the auxiliary workers along the internal distribution route at fixed frequency.

The workshop address system divides workshop production area by address coordinates. “Plan for every part” manage all parts information from customer to supplier with database. Production Kanban management integrates logistics and information flows to indicate the start and end of production. Anton alarm system timely issues producing anomaly signal to stop the problem product output.

Value flow management is the premise of lean production. The current state value flow diagram describes the whole process from raw materials to finished products, and finds out the waste and unreasonable links in the production process from the customer's point of view. The future state value flow diagram should aim at improving the production process, shortening the production lead time and eliminating waste and design production improvement plan in accordance to lean mode. In value flow management, both current and future state value flow analysis revolves around logistics and information flow. [5]

From the above explantion, the main management tools and methods of lean production are closely related to logistics, and logistics function plays a crucial role. In the past, the study and application of lean production focused on the concepts and technical methods of lean production management, but lacked the understanding of lean production logistics system, which limited the research and application of lean production to a certain extent.

2. Transformation of logistics function under lean production

Under lean production conditions, the core of the exertion of logistics functions such as storage, transportation, handling, circulation and processing, packaging, distribution and information processing, supplier coordination, and so on is to minimize inventory, reduce waste, and improve production efficiency. The traditional significance of logistics function has been transformed.

2.1 Warehousing and material turnover

The lean production takes "zero inventory" as the goal to pursue, and the raw materials and finished goods warehouse under the condition of mass production is canceled, which is replaced by the material receiving and sending sites characterized by dynamic flow. The warehouse used to store a large amount of materials was changed into a buffer supermarket composed of mobile shelves,

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which greatly reduced the total inventory, and the field operation also changed from "storage and custody" of materials to "turnover distribution".

Under the condition of mass production, the way to cope with the change of orders and guarantee the delivery time is to store a large number of works in process, and the lean production uses buffer supermarket to replace the warehouse of work in process and strictly controls the quantity of work in process on the production line. The way to deal with the change of production caused by the fluctuation of order is to keep a certain inventory in the finished product supermarket so as to keep the balance and stability of the production process.

2.2 Transport and material distribution

Workshop transportation depends on the early equipment layout to a great extent, once settled, the transport is no longer the core of production logistics. According to the principle of object specialization, lean production arranges equipment in U type to constitute product production cell, and the production flows counterclockwise so that the transportation of products is the least and the distance is the shortest. Workshop internal distribution route planning is reasonable with obvious visual signs. The material distribution is completed by the auxiliary workers, and it is regularly submitted to the production station under the pull of Kanban, and the finished product or empty turnover box are recovered. The material collection and finished product delivery are no longer completed by the production workers so that the use ratio of effective value-added time is improved.

In order to reduce the waste of workers' actions, the parts delivery device is used in the work site to transfer materials. According to the principle of action economy, the chute, conveyor belt, ejector, rotating box and so on are designed, which are convenient for the workers to take and submit. "5S" management and visual management are implemented in the production site, achieving "things have their place, things are in their place" and keeping the site environment clean and orderly.

2.3 Repackaging and material handling

Turnover box is used for transferring material between lean production processes. The raw materials or parts are sub-packed, sorted and assorted before being processed to ensure small batch, multi-varieties and rotation production requirements.

Sub-package refers to the process of packing parts supplied by suppliers from

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large packages to small turnover boxes for production. If agreement is reached with the supplier, this step can be completed directly by the supplier. (Figure 1) What needs to be clear is that as the lean production level increases, the quantity of materials in the turnover box will gradually decrease until the turnover box is no longer used, resulting in "one piece-flow cell".

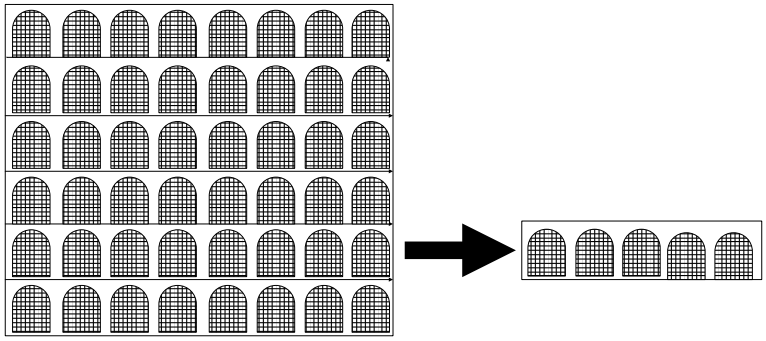

Figure 1 Sub-package

Sorting refers to the process of placing the processing objects with the same processing technique and different specifications in the turnover box or tray in accordance with the processing order, and the operator rotates them in order (Fig. 2). Sorting is also one of the common methods of group processing technology.

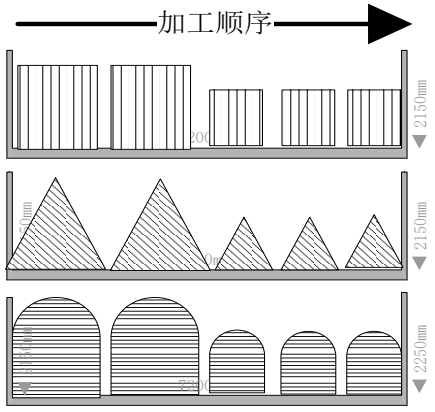

Figure 2 Sorting

Assorting refers to the preparatory work that the necessary parts and components are placed on the tray in advance before the finished product is assembled, and then sent to the assembly workshop, which can reduce the time for workers to walk around looking for spare parts (Fig. 3). [6] [7] [8]

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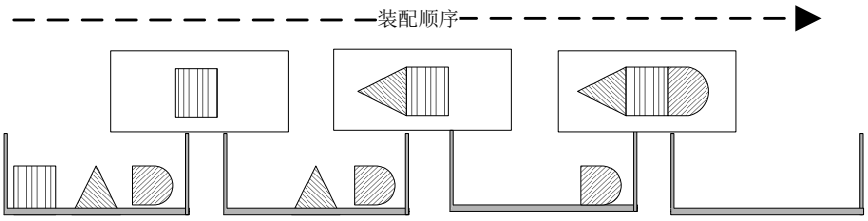

Figure 3 Assorting

2.4 Information processing and supplier pull

In information processing, lean production is manifested in synchronization of logistics and information flow. Value stream management specifies the routes and links of logistics and information flow, the workshop address system specifies the location of facilities, equipment and items, and the "plan for every part" contains all the information for each part from customer to supplier. Kanban (Japanese) management realizes the unification of information flow and logistics and Anton system feeds back the abnormal production information to the relevant personnel at the fastest speed.

Supplier pull is the extension of enterprise Kanban (Japanese) management from inside to outside. On the basis of establishing a common interest alliance with suppliers, it can reach the purpose of directly delivering materials to production sites and reducing logistics links. On the basis of improving the internal Kanban pull system, the enterprise gradually promotes the supplier pull, and finally forms a complete supply chain management system.

2.5 Organizational support for lean production logistics system

In order to ensure the unity and coordination of production and logistics, production logistics center (P & L) should be established, which is responsible for the completion of the responsibilities including verifying material and labor quota, establishing operation standards, production site management, material procurement, delivery of finished products, supplier contact and so on, and to promote lean production improvement by adjusting material quotas, and reducing the number of Kanban. [9]

3. The objectives and the structures of lean production logistics system

3.1The objectives of lean production logistics system

Production logistics system aims at supporting lean production, improving continuously and realizing supply chain integration. The specific manifestations

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are:

(1) The product delivery site effectively controls inventory, keeps production balance and continuity in order to 100% meet customer needs.

（2）Through continuous improvement, the material receiving site can reduce the stock and push the supplier to implement Kanban pull supply.

（3）Plan workshop transportation route and set up distribution recycling system. Assist production workers to distribute and recycle materials, direct production workers no longer receive and feed, reducing non-value-added time.

(4) The material delivery device is designed according to the principle of action economy, which is convenient for the production workers to take and use and reduces the waste of action.

(5) Replace the WIP warehouse with small shelves between working procedures for temporary storage of raw materials, WIP and empty turnover boxes.

(6) Set up the workshop address system, the production area is marked by coordinates to specifying the location of the items.

(7) Logistics has the same direction with value flow and process flow, Kanban pull material movement.

(8) Formulating “plan for every part” and build part database management system from customer to supplier.

(9) Designing the Anton system to send out the abnormal production alarm signal in time.

（10）“5S management” and “Visual management” are implemented on site.

3.2 The structures of lean production site logistics system

Lean production logistics system is composed of logistics such as finished product delivery site, material receiving site, internal distribution route, material transfer and so on, as well as information flow such as value flow, process flow and production rhythm.

(1) Finished products delivery site

Product delivery sites include product buffering supermarkets, cargo turnover site, vehicle stopping points, transport corridors, empty turnover box storage sites, and corresponding logistics facilities, equipment and personnel. Lean production allows for a certain amount of finished product inventory to buffer order fluctuations so that the buffering supermarket at the sending site should leave enough finished product storage space. The reusable turnover boxes returned by

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customers should be stored in specified temporary storage points, and should be returned to the production process by the auxiliary workers timely. Cargo turnover sites are used to sort, send, and receive goods, and vehicle stopping points and transport corridors are designed according to means of transport and mode of transport. Product delivery site does not use large logistics equipment, while using small auxiliary equipment to handle materials as far as possible.

(2) Material receiving site

The nature of the receiving site is similar to that of the delivery site, but the flow direction of material and empty turnover box is the opposite, that is, the material flows in and the turnover box flows out. The material buffering supermarket is close to the transport corridor, saves space as much as possible, and the visual signal marks the material storage position. The whole piece handling material is placed on the moving shelf, the bulk material (liquid or powder) is packed in containers to set aside the storage space of the empty turnover boxes. Empty turnover boxes are bundled back to suppliers and shipped back by delivery vehicles.

Material procurement and production requirements should maintain coordination. For raw materials or spare parts of single variety, large volume, strong repeatability, frequent use, the supplier Kanban pull should be given priority.

(3) Internal distribution route

Internal distribution route refers to the internal transportation route of workshop which delivers material to production station and recover empty material boxes and finished products. In order to balance production and control the quantity of WIP, the workshop implements small batch and frequent distribution, uses small means of transport, and conducts manual material handling as far as possible. The distribution route has clear signs of traffic and stop.

(4) Material handling site and delivery device

Designing the material processing area in the material receiving site or the designated position in the workshop (also can be outside the production workshop), which can be used for material earlier stage processing, such as sub-packing, sorting, assorting and so on.

Material delivery devices should be designed next to the production station, and the distribution personnel shall place the materials on them to be used by the

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production workers. Material delivery devices can be designed as chute, conveyor belts, ejection devices, rotating boxes, etc.

(5) Value flow, process flow and production rhythm

Logistics should stay at the same direction with value flow and process flow, and logistics links are designed according to lean production requirements to make the material flow the shortest and transportation workload the least. Value flow chart, process flow chart, and production rhythm are important parameters of logistics system design. Value flow chart indicates logistics path, product process flow indicates logistics links, while production rhythm and order indicate material distribution time and frequency.

(6) Workshop address system

The address system starts from the northeast corner of the building, divides rows and columns according to a certain size interval, divides the production area into standard spacer regions of equal area, and marks them with row and column numbers (Fig. 4). Items in the spacer region are encoded in sequence, which should realize "things have their place, things are in their place". Geological system is of great significance for the effective implementation of visual management, the improvement of resource utilization, the elimination of waste, and the improvement of field management level.

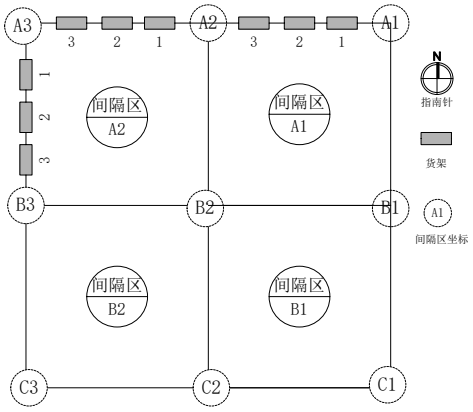

Figure 4 Workshop Address System

(7) Plan for every part

From the customer backtracking and from the production workshop to the supplier, a database of all spare parts information, including part number, weight, size, storage warehouse, storage conditions, use process, matching quantity, package quantity, package size, consumption speed, external or self-production, supplier name and location, mode of transport, frequency of transmission, etc.

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must be established. The parts plan plays a key role in the coordination of information transfer and logistics control and can effectively support the implementation of lean production.

(8) Kanban (Japanese)management and Anton system

The production Kanban indicates the start and end of the operation, and the taking material Kanban pull the material to move between the operations. Based on product and production site conditions, Kanban can use information cards, rolling balls, turnover boxes, electronic billboards and other visual indicators. The Anton system can issue abnormal production information in time, and the management personnel will receive the signal and arrive at the scene in time until the problem is solved and the production is resumed.

Value stream, process flow, production rhythm, workshop address system, plan for every part, Kanban management, Anton system constitute the main body of lean production information flow [10][11][12].

4. Operation and management of lean production site logistics system

4.1 Sending area operation management

Sending area operation management includes clearing job responsibilities, formulating work standards, scheduling activities, managing site maintenance, balancing allocation of resources, handling exception, etc.

At the beginning of the working day, the manager arranges the work activities with the job instruction Kanban (Table 1) according to the product delivery plan given by the production logistics center, monitors the completion of the work at any time after the work starts, and marks it with symbols or colors. The work arrangement is balanced and orderly, can use the resources effectively, and guarantees the safety production.

The communication channels between the job site and the delivery driver and the customer are smooth, and the transportation and arrival conditions are known in time. If an accident occurs during transportation, the driver reports to the management personnel in a timely manner and promptly takes remedial measures. The empty turnover box shipped back is placed at the designated location, sent to the assembly area by the staffs sending materials, and return the finished products.

Site cargo should do the turnover timely, handling wooden pallets to avoid causing site congestion. Finished product delivery is consistent with the

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production Kanban pull to keep the total inventory minimum. At the end of each class, all personnel gather together to summarize and discuss, propose improvement measures to the problem, and fill out the countermeasure form (Table 2).

Table 1. Operation Indicator Board

Time	Date: May.16.2011 Shifts: 1		
	Sending station 1	Sending station 2	Sending station 3
8:00	Customer: A Products: Wp、Wq Transport vehicle: S1 Complete status: Ⓩ		Customer: B Products: Wp、Wq Transport vehicle: S2 Complete status: Ⓩ
8:30		Customer: C Products: Wq Transport vehicle: S3 Complete status: Ⓦ	
9:00	Customer: D Products: Wp、Wq Transport vehicle: S4 Complete status: Ⓨ		Customer: E Products: Wp Transport vehicle: S5 Complete status: Ⓩ
9:30		Customer: F Products: Wp、Wq Transport vehicle: S1 Complete status: Ⓠ	
10:00		Customer: A Products: Wp Transport vehicle: S2 Complete status: Ⓩ	
10:30	Customer: B Products: Wp、Wq		

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	Transport vehicle：S3 Complete status：Ⓩ		
11:00			Customer：D Products：Wp、Wq Transport vehicle：S4 Complete status：Ⓨ
11:30	-----	-------	-----
Note： Ⓩ（Green）Arrive on time Ⓨ（Red）Transportation delay Ⓠ（Red）Product shortage Ⓦ（Red）Shipment delay			

Tab2 Countermeasures

Reason	Date	Time	Carrier	Problem / behavior	Countermeasure
W	5/16	8:30	S3	Cause of shipment site-delay	Increase staffs
Y	5/16	9:00	S4	The truck is 25 minutes late-the third time this week	Transport notice, replacing carrier if necessary
Q	5/16	9:30	S1	Shortage of T03 spare parts	17 May truck shipment replenishment
Y	5/16	11:00	S4	Truck 45 minutes late-heavy rain	
Note：Y ——Transportation delay Q——Product shortage W——Shipment delay					

4.2 Goods entering area operation management

The goods entering area operation management is close to the sending area, but the site organization and management are relatively complex.

At the beginning of the working day, the job instruction Kanban is used to arrange daily work activities, including the type, quantity, storage location and shelf number of the materials received, and mark the completion situation with symbols and colors in time after the start of the operation. Work standards are implemented on site, and safety production is at the top priority.

The communication channels between managers and suppliers and delivery drivers are smooth, and the shipment status is timely informed. After the material

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arrives, it will be quickly organized and received. The materials will be fed as much as possible on a daily basis to keep the material supply consistent with the production requirements. For the manufacturers that pull the supply, the receiving personnel pay attention to the recovery of the Kanban, and send the supply signal to the manufacturer again when accumulating the required quantity, and the driver will return to the turnover boxes provided by the supplier on the return journey.

At the end of each shift, the management personnel convene all the staff to summarize the completion situation of the work, fill in the cause and solution in the countermeasure form if there is problem, encourage employees to make reasonable suggestions, continuously improve, and reduce inventory level.

4.3 Material storage management

Receiving area material buffering supermarket stores materials, whose activities include: planning blank parts, storing bulk materials (plastic granular materials), emptying turnover box storage, distributing materials to the production site, emptying turnover box recycling, and conducting sub-packaging, sorting or assorting treatment. The whole material is placed on the moving shelf with a turnover box, putting into from one side and taking from other side, and adhering to the principle of "first in, first out". Bulk materials are stored with large containers, also complying with "first in, first out" principle, marking safe stock location. The recovered empty turnover box is placed in the designated location and the taken back by supply vehicle.

4.4 Material distribution

Material distribution includes internal distribution route planning, material distribution, the recovery of Kanban, finished products and empty material boxes and so on.

The production unit processing equipment is arranged according to U type (the material moves counterclockwise), the feeder places the blank turnover box accurately on the material delivery device from the unit entrance, and the quantity of material is the same as the number indicated on the Kanban, and take the finished parts from the exit of the unit upon departure, and recover the empty material box regularly at the same time.

All distribution work should be completed according to the route, distribution frequency and quantity of delivery, and the number of workers should be adjusted flexibly according to the order and production rhythm. The feeder should be taken

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up by the workers who have been simplified after the improvement of lean production. As far as possible, large-scale logistics tools such as forklifts and handling devices are not required at the production site, and small manual handling equipment is mainly used. The distribution process is mainly based on small batches, multiple varieties and frequent distribution, in order to achieve balanced production targets of multiple varieties and small batches.

4.5 Material handling

A sub-packaging and sorting processing area is set up near the receiving buffering supermarket, and an assorting area is set before the final assembly process. Sub-packaging and sorting ensure small-volume, multiple variety rotation production, and assorting avoid the messy parts of the assembly site and save assembly workers from walking around to find parts. After pre-processing of materials, workers no longer have to waste time taking out paper packaging, plastic bags, splitter plate or liners, which can quickly assemble the finished product.

In addition, the production site implements "5S management" and "visual management"., which makes “things have their own place and things are in their own place”. Workshop is clean and bright, staff are proud of this and develop a good habit of consciously maintaining the environment. Kanban pull, process synchronization, rapid switching, multi-functional work and other lean production management technologies can be successfully implemented. [7]

5. Application cases

At present, two kinds of Wp,Wq products of different models of W series are produced in an enterprise, which are composed of machine add-ons $T01_{(p.q)}$、$T02_{(p.q)}$、$T03_{(p.q)}$, injection molding S01 and a small amount of external auxiliary parts κ respectively. That is, Wp（$T01_p$、$T02_p$、$T03_p$、S01、κ）、Wq（$T01_q$、$T02_q$、$T03_q$、S01、κ）. Blank parts $T01_{(p.q)}$、$T02_{(p.q)}$ shall implement suppliers Kanban pull, blank part $T03_{(p.q)}$ and S01 plastic granular raw materials are purchased in large batch. The layout of the workshop after lean production transformation is shown in figure 5. The workshop is divided into product delivery area, material receiving area, material supermarket, T01 processing zone, T02 processing zone, T03 processing zone, S01 injection molding area, assorting area, assembly area and management service area according to the address system.

The supply of blank parts $T01_{(p.q)}$、$T02_{(p.q)}$ in the production site should

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implement Kanban pull. Suppliers use special turnover boxes according to the purchase contract, which can be transported directly to the production site. T03 (p.q) blank parts should be sub-packed from large packing to small turnover boxes in the receiving area material supermarket. S01 is not sorted, which is produced according to the matching quantity. External parts and accessories have a small amount of consumption and occupy small space, and are distributed quantitative once every working day so that do not give specific elaboration.

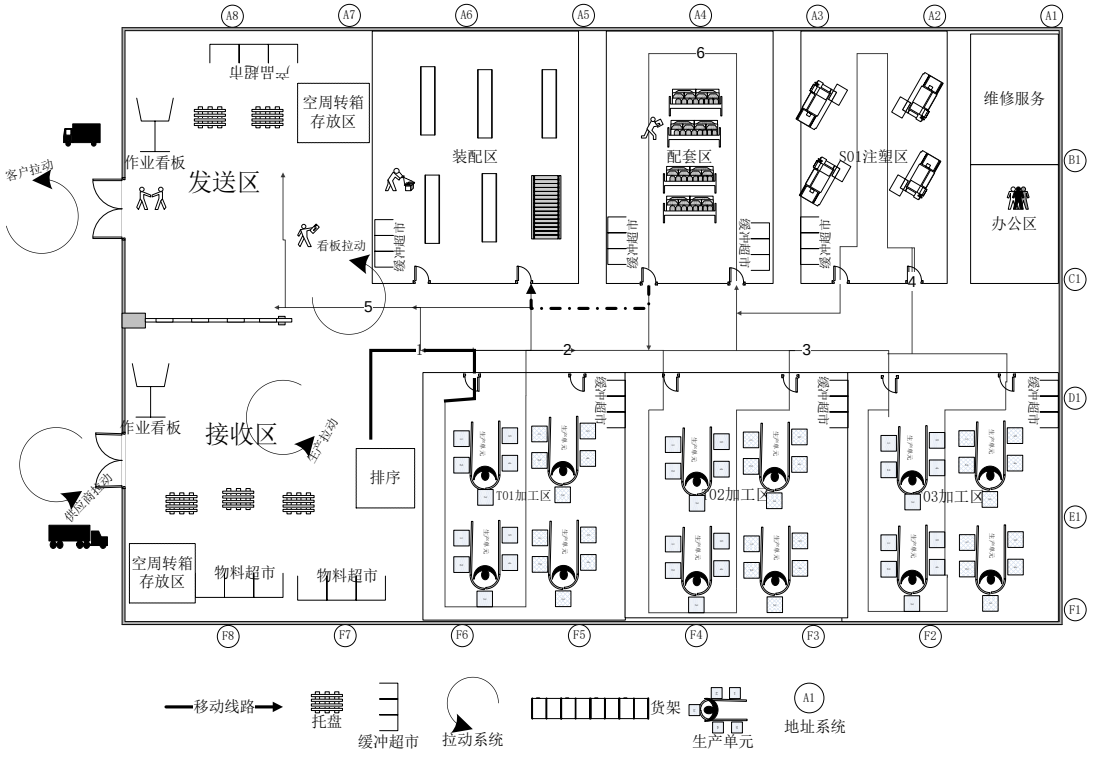

Fig 5 Production site layout

The material distribution process at the production site is completed in three stages.

(1) If Wp and Wq are produced in batches, the T01 (p,q)、T02 (p,q) blanks are directly sent to the production station, and T03 (p,q) is repackaged in the receiving area material supermarket. If these are produced in the same batch, the T01 (p,q)、T02(p,q)、T03(p,q) blanks are sorted according to the processing quantity requirements of Wp and Wq, and loaded into the turnover boxes to be transported to each production station. After leaving, the finished parts are sent to the assorting area, and the empty turnover boxes are transported back to the material

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supermarket when leaving the assorting area. S01 plastic raw materials shall not be sorted, the feeder directly transports it to the injection processing zone, which is produced according to the matching yields. When leaving, the feeder brings the finished injection molded parts to the assorting area, then sends back the empty turnover boxes to S01 injection molding area, back to the material supermarket.

(2) The parts and components of the Wp,Wq used for assembly are put into the special turnover box in the supporting area, and transported from the matching area to the assembly area, and when returned, the empty turnover box is transported back.

(3) Assembly area completes assembly, packed with standard packaging to send to the sending area, return to empty packing box.

The equipment of T01 / T02 / T03 processing unit is arranged in U shape (moving counterclockwise), the feeders put the blank turnover box on the material delivery device accurately from the entrance of the unit, and the quantity of materials is the same as the quantity indicated by the Kanban. The feeders use a special trolley to transport raw materials to the S01 injection modeling area, and the bulk granular plastics are stored in a container with metric scale, and the safety inventory sign was made, which was used as a pull supply signal. There is no WIP warehouse in the workshop. Mobile shelves between processes serve as buffering supermarket for a small number of WIP turnover. The workers of the assembly area put the T01, T02, T03, S01 parts into the special turnover box and send them to the assembly area before assembling.

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