



## Learning Objectives for This Chapter

- Role of layout planning in SCOM
- Layout planning in manufacturing
- Layout planning in warehouses
- Methods of layout planning.

---

## 10.1 Introductory Case-Study “OTLG Ludwigsfelde”

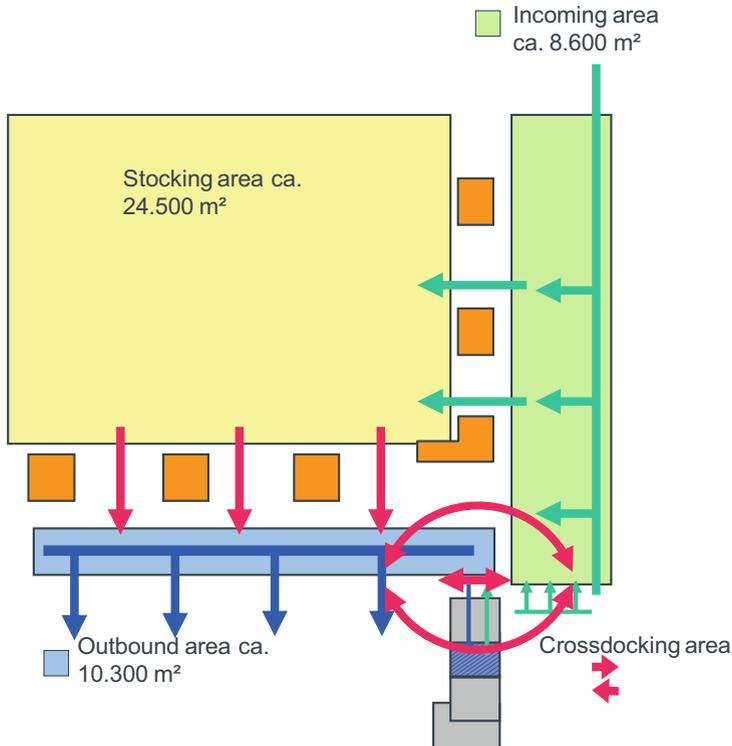
Volkswagen Original Teile Logistik GmbH & Co. KG (OTLG) is a service partner for the spare parts of Volkswagen, Volkswagen Nutzfahrzeuge, Audi, Seat, and Škoda. OTLG is part of the wholesale level of the SC and is responsible for sales and marketing in Germany. At present, OTLG operates in seven distribution centers in Germany. After locating a new distribution center, the layout planning has been done as follows (Fig. 10.1).

The warehouse layout includes an incoming area for the receipt and inspection of goods. If an order for the supplied item already exists, the item is moved via the cross-docking area directly to the outbound area. Otherwise, the items are first stocked and then put away, and then picked up after an order is received. Such a layout ensures the shortest transportation routes and the efficient placement, put away, and pick up of items with the help of sophisticated software and automated material handling technologies.

On the basis of this case study, describe the basic processes and areas in warehouse logistics layout.

---

Find additional case-studies, Excel spreadsheet templates, and video streams in the E-Supplement to this book on [www.global-supply-chain-management.de](http://www.global-supply-chain-management.de)



**Fig. 10.1** Layout planning at OTLG in Ludwigsfelde

## 10.2 Layout Planning in Manufacturing

In Chap. 9, the process flow structures were presented, and it became evident that the underlying parameters which determine which process flow structures should be used are volume and variety. The process flow structures do not as such indicate what type of manufacturing layout is best, but layout types are closely linked to the processes applied to create a product.

A layout is the physical arrangement of objects in space. Fundamental objectives related to this are as follows:

- to limit travel distances between machines or departments;
- to allocate departments or functional areas/main production areas in a reasonable pattern;
- to avoid crossing flows (material, transportation devices, human beings, etc.);
- to prepare for later adaptation or expansion.

In general, there are four basic types of layouts in manufacturing and these are:

- fixed position layout,
- process flow layout,
- product flow layout,
- cell-based layout.

### 10.2.1 Fixed Position Layout

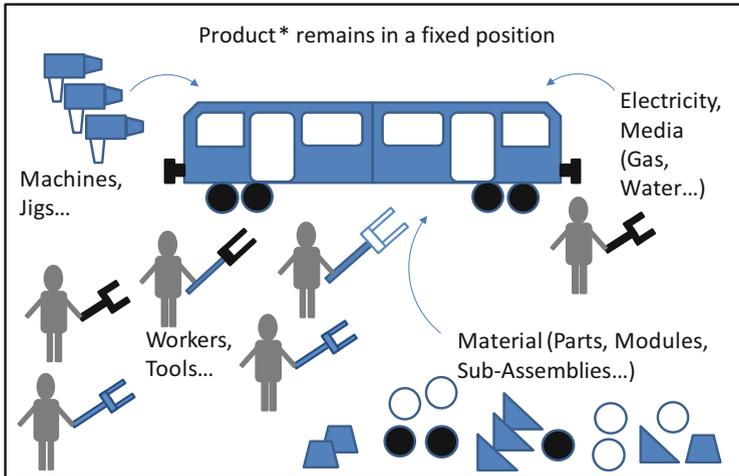
We start with the *fixed position layout*. As the name indicates, in this type of layout the product or object remains in a fixed position while value is being added. Imagine that there is construction work going on in a city: all workers, tools, machines, and parts are brought and placed at the location where the work is performed. The same is also valid for a movie set, where the technicians, actors, cameramen, directors, etc. come to the location where the movie is shot.

Now that we have this understanding about the meaning of a fixed position layout, we discuss the manufacturing environment. A similar approach to the movie example can also be applied in operations where the volume of goods produced is rather low and where the product is extremely heavy or bulky, i.e., difficult to move around. Examples are locomotives/trains, airplanes, or electrical power windmills. In all of these cases, the product remains at the same location for a very long period of time and the materials need to be brought close to the point of value creation.

On the *production floor*, certain designated areas need to be defined where the parts or components will be placed by logistics/material movement staff. Footprints (= marked areas on the factory floor) need to be defined where the necessary material will be buffered. The workers will need to walk back and forth from the material buffer to the product to move material to the product. The same transportation effort also applies to tools, machines, or media (such as electricity, gas, or water).

To give a practical example, imagine the assembly of a locomotive in a factory facility. All necessary parts are buffered outside, so that the workers need to pick them up and carry them inside the locomotive in order to conduct the final assembly, which is inside the locomotive. As this example implies, the flexibility to e.g. change the sequence of assembly work packages is quite high in a fixed position layout set-up.

In addition, the impact of defective tools or machines is not that intense, as the layout provides an opportunity for replacing the machine and then continuing to work. At the same time, aspects of motion and movement (walking, waiting, searching), or the relatively high possible levels of buffered inventories are disadvantages of this layout system. The symbolic illustration below shows the



\*Useful for heavy, bulky products such as a locomotive, for example

**Fig. 10.2** Principles of the fixed position layout

motion and movement of the media, workers, tools, etc. in a simplified way (see Fig. 10.2).

- ▶ **Practical Insights** *In essence*, for the production of a few heavy, bulky products, the fixed position layout is a good choice, since it provides the advantages of flexibility and adaptability. On the other hand the disadvantages are the high amount of unnecessary motion and movement.

## 10.2.2 Process Flow Layout

In the case of further processing of e.g. metal parts or metal products, the process flow layout is another basic type of layout. The key principle is that the operational environment is split into specialized functional areas, for example, a department where metal is cut, another department which is specialized in drilling, another one specialized in milling, etc.

Such a layout of specialized functional areas in manufacturing is quite similar to the layout of a hospital, where you have first aid, the ophthalmologist, internist, or the cardiologist ward.

In metal manufacturing, product 1 might first require a drilling operation, then some milling, and finally some welding. Product 2 might first require bending, then drilling, milling, and then welding. What becomes obvious is that the sequence of processes that need to be performed determines the product flow between

departments. This is also the reason why this layout type is called a “process flow layout.” The advantages are that the layout is quite flexible, since it allows the production of a very high number of very different products (of course they need to be created under usage of similar production technologies and machines, as explained above) in relatively high numbers.

The disadvantages are production in particular lot sizes, the high transportation effort, and the danger of having quite a high number of crossing/contradicting material flows. As the departments are in principle specialized, multiple machines are also likely to be available in e.g. the drilling department (see Fig. 10.3).

The process flow layout is not very vulnerable to the breakdown of machines. If drilling machine 4 breaks down, maybe the product can alternatively be produced using drilling machine 5, for example, as Fig. 10.3 depicts. In order to understand Fig. 10.3, the following short explanation regarding the hypothetical case above is given. Product A is first processed on drilling machine D2, then it is moved to milling machine M4, and then it is welded on W2. After this, the product is painted in paint shop P1. Finally, the packaging and shipping preparation take place. Next or possibly simultaneously, product B is moved through the facility, and processed on machines B6, D1, M2, W1, and P2. As indicated above, products A and B flow through the manufacturing department according to the relevant process steps.

As illustrated in Fig. 10.3, the flow might become almost chaotic. This is referred to as a “spaghetti flow illustrated as a spaghetti diagram” in lean thinking terminology.

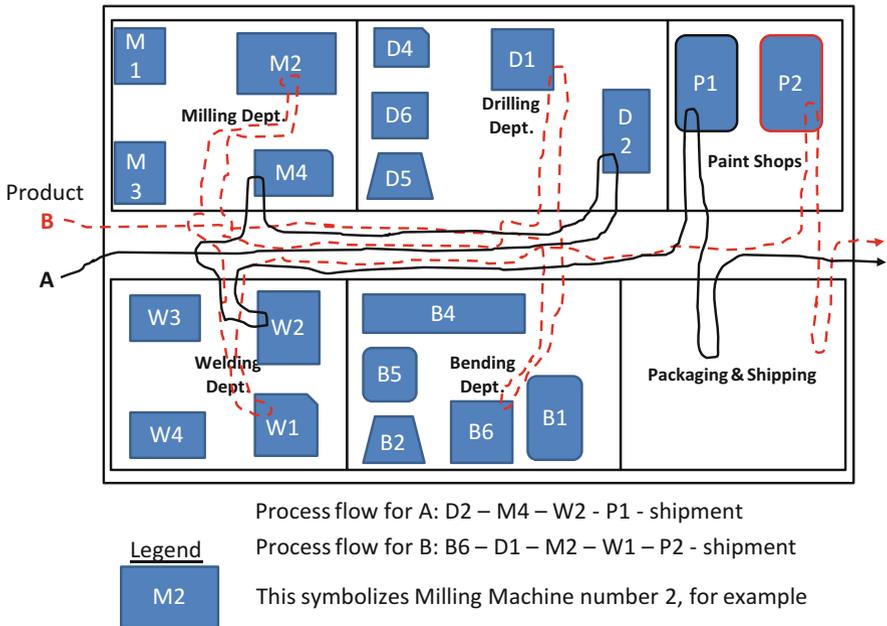


Fig. 10.3 Principles of the process flow layout

- ▶ **Practical Insights** *In essence*, for the production of hundreds or thousands of similar (metal) parts, the process flow layout is a good choice, since it provides the advantages of flexibility, general usability, and has a relatively low level of vulnerability. The disadvantages are the high amount of unnecessary motion and movement and crossing material flows.

### Process-Flow Layout: A Practical View

Figure 10.4 shows the bay of the factory where machine-centers for the creation of high-tech break disks are installed. The minimization of the transportation distances between the machines was the fundamental principle of the layout planning. The machine allocation ensures a flow for the performance of a series of specialized processes. In this specific case, the flow is structured in the following way: turning—milling—drilling. Non-destructive testing is also one of the processes that can be performed along with the in-process removal of burrs or the balancing of the break disks.

“High flexibility” is key criterion to this layout design. The production processes that are performed on multiple machines require the object be moved from one machine-center to the other centers. This can be implemented in the layout developed. In principle, all the product flows according to the production processes are possible.



**Fig. 10.4** Machine-centers for turning, milling, and drilling (© Knorr-Bremse Berlin SfS GmbH)

Figure 10.4 depicts the major lean principles. For example, visualization boards showing material availability, Pareto charts on quality KPIs, check sheets or charts showing adherence to production progress are placed on the shop floor. The objective is to obtain transparency regarding the planned and actual production progress, to respect the *5S principles* (sort, systemize, sweep, standardize, sustain—in Japanese *seiri, seiton, seiso, seiketsu* and *shitsuke*) and to secure TPM (*Total Productive Maintenance*). Furthermore, the standardized color-coding clearly indicates the footprints for raw-material and finished goods.

The break disks are produced in specified lot-sizes (batches) (see also Chap. 13) and subject to the storage capacity of the shelves on the shop floor that define the respective batch sizes. For example, if the storage capacity of a shelf equals 20 units, a batch-size of 30 units would be impossible.

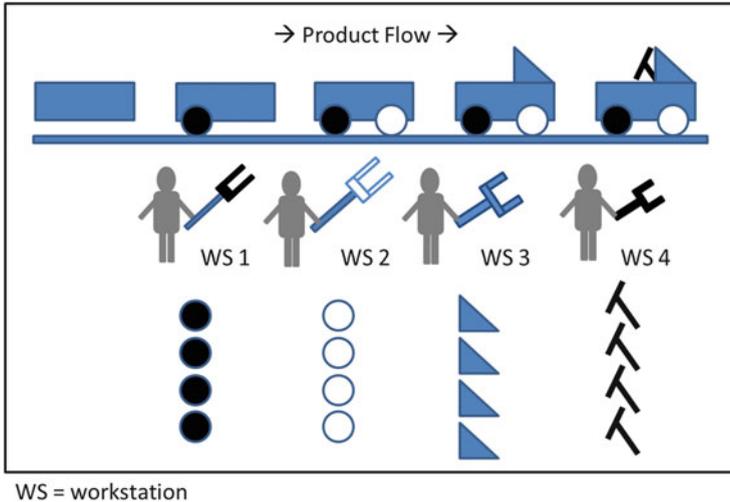
The setup of the manufacturing area in Fig. 10.4 is very flexible. It makes it possible to implement alternative flow patterns according to the required processes for the creation of the respective product. This is a very good example of a “process-flow layout.”

### 10.2.3 Product Flow Layout

The key idea of this type of layout is that the product being created moves through a series of specially designed and equipped workstations. It could be that the product will be moved with a conveyor system (such as an assembly line for the production of cars or household devices), but it could also be that the product is moved through the defined workstations manually (e. g. production of converter boxes for the railway industry).

Usually, this type of layout is considered when a very high number of quite similar products are produced, for example 1000 cars per day. It is important for a properly working product flow layout that the product moves through a facility with the same speed (see Fig. 10.5).

For example, it might be that the product moves at a beat (or pace) of e.g. 90 seconds from workstation to workstation. In principle, the different stations are equipped with all necessary machinery and media, and the material required to be installed into the product at that station is also buffered at the station. This means each and every station is designed for a special purpose. If you think about car assembly, you have an early station where the cable harnesses are placed into the car, after which the carpets are installed, followed by the seats, and so on. The sequence is important, but so is the duration of the work that needs to be performed, as well as supporting technology and the necessary space for the material that is required at the respective station. With respect to the logistics and the placement of materials, the exact number of parts needs to be identified prior to planning the layout since they must be buffered right next to the assembly station at the line, so that everything (the



**Fig. 10.5** Principles of the product flow layout

product, the parts to be installed, the tools, and media) is within easy reach. These parameters, parts, processes, tools, media, etc. have a significant influence regarding the dimensioning of the layout.

The product flow layout can also be applied to the creation of household appliances such as washing machines, refrigerators, or microwave ovens, or for sport shoes, etc., and the production volume needs to justify the special arrangements of the workstations and the necessary tooling. The advantage is that the products can be assembled in a very efficient way: the product flow is longitudinal and the timing is very well balanced, according to the defined pace (beat rate) of the product that moves through the production facility in a one-piece single flow mode. Besides these obvious advantages, there are also disadvantages: if parts are missing or defective, or when a machine or tool breaks down, the product flow will be interrupted. While the layout results in high efficiency, it is also highly vulnerable.

- ▶ **Practical Insights** *In essence*, for the production of thousands of similar products (such as cars or household appliances) per day, the product flow layout might be a good choice, since it provides the advantages of efficiency and smooth flow at a given pace along specially defined, designed, and technically equipped workstations. The product flows over these workstations at a constant cycle time. The disadvantage is the high probability of interruptions or stoppages in the event of missing parts or defective machines.

### **Product-Flow Layout: A Practical View**

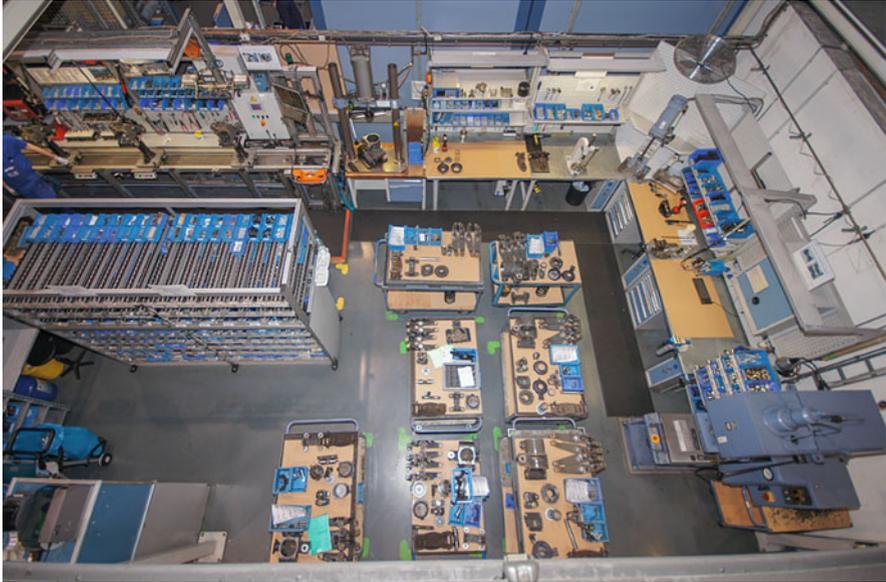
In the labor-intensive after sales and services business areas with their rather low production volumes and high variety, the fundamental manufacturing layout with a

steady *product-flow layout* combined with lean principles can also be implemented (see Fig. 10.6).

In this specific case, the used break systems are refurbished in a special area of the factory. Although there is no conveyor belt, the general assembly line principles (see Chap. 9) were applied when the layout was designed. Figure 10.6 depicts the final assembly of the refurbished break systems as the product moves through a set of



**Fig. 10.6** Product—flow layout/assembly line for refurbishment processes [front view] (© Knorr-Bremse Berlin SFS GmbH)



**Fig. 10.7** Product—flow layout/assembly line for refurbishment processes [top view] (© Knorr-Bremse Berlin SFS GmbH)

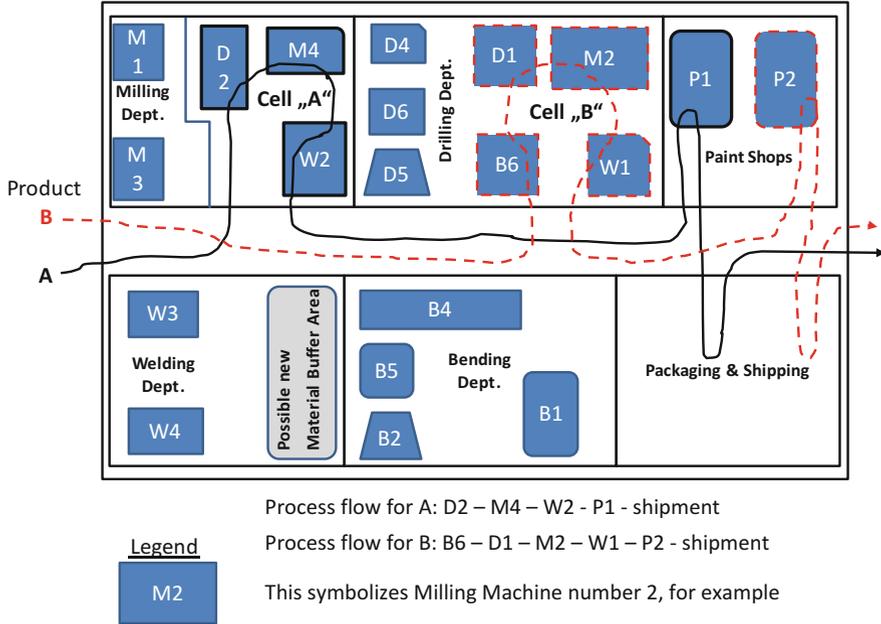
especially designed workstations following a steady timing. This is also called *takt time* (see also Chap. 9), which “is the rate (time per unit) at which the system must produce a product to meet external customer demand” (Martin 2007).

Prior to the final assembly, the used break systems received are checked in the initial goods reception processes. Following this, the disassembly and cleaning of the received systems take place (Fig. 10.7).

Pre-kitted sets of new replacement parts and other required assembly materials are provided to the assembly line along with the cleaned and disassembled components on trolleys. Visual media and footprints on the floor mark the individual positions for the trolleys, as shown in Fig. 10.7. Furthermore, tools and jigs are placed within easy reach respecting the *best point philosophy* for an *ergonomic workplace*. Figure 10.7 clearly shows that for smaller series with high manual efforts, the fundamental principles of the “product-flow layout” can be effectively applied.

### 10.2.4 Cell-Based Layout

In the case of the *cell-based layout*, the advantages of the product flow layout (smooth flow) and process flow layout (flexibility) are combined. This type of layout is also called a hybrid layout or is referred to as the grouping of technology. The main idea is to group the machines, tools, and equipment required in the exact



**Fig. 10.8** Principles of the cell-based layout

sequence of the production steps so that there will be no crossing of the materials and transportation distances are minimized.

In such a case the product is created by moving through the cell. Most likely, the pallets with the in-production products (semi-finished goods) are moved from one machine to another manually, i.e. in most cases there will be batches of products produced per machine, and when they are finished on that particular machine, the lot is moved to the next machine or station (see Fig. 10.8).

In most cases this is not a single piece flow, but most often a flow of batches. Despite this inefficiency, there will still be a kind of smooth flow. In contrast to a real assembly line, the alignment of the machines in the cell is cheaper, and with reasonable effort the cells can be rearranged to make other products.

Figure 10.8 shows products A and B and their production sequence as it was introduced for the process flow layout. The following illustration considers the generation of two cells. One for the creation of product A and the second for product B. As one can see, the flow of products becomes almost one directional and the crossing of the material flows is significantly reduced because of the rearrangement of the required machines.

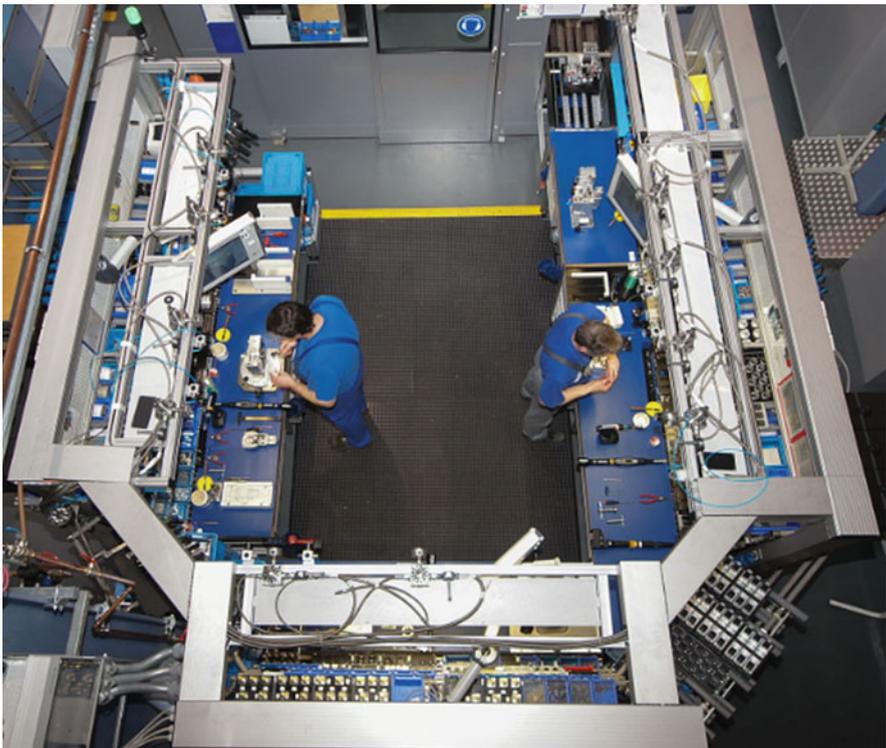
- ▶ **Practical Insights** Please note that for some machining, such as welding, an exhaust evacuation system might be required. Space constraints or certain media connections will need to be assessed in this regard.

*In essence*, for the production of similar products (such as computer chips, sub-assemblies, lamps, etc.), the cell-based layout is a good choice, since it provides the advantages of a smooth product flow layout and the flexibility of a process flow layout.

### Cell-Based Layout: A Practical View

In Fig. 10.9, the assembly of valves in a *cell-based layout* is depicted. The developed layout considers a balanced one-piece-single-flow that runs in a counter-clock-wise manner. The operational processes start on the upper left-hand side. It can be observed that the cell has a typical “*U-shape*.” After the product has moved through the cell and reached the upper right-hand point, all necessary production steps are finalized and the handover to the inspection department takes place.

The applied layout design strictly separates the operators and their value-adding working environment inside the very well illuminated U-shape from the material replenishment processes which take place outside the cell. The workers continue their work in the center of the cell while new material is fed into the cell and empty



**Fig. 10.9** Assembly of valves in a cell (© Knorr-Bremse Berlin SfS GmbH)

bins are collected from the outside. This ensures disturbance-free operation on the process side and the availability of secured material.

All tools, machinery, and material can be easily reached. *Lean ergonomics* criteria, adjustable best point locations and positions, as well as the *5S principles*, have also been considered in the creation of the cell-based layout. Furthermore, the screens show the standard operating instructions. The torques of the machines and the usage of lubricants are automatically supervised in order to secure *zero defects* throughout all the production steps.

Such a concept eliminates non-value adding times, securing the highest quality outputs while the operating processes are balanced and conducted in the most ergonomic way all at the same time. The manufacturing area shown in Fig. 10.9 is a very good example of a “*cell-based layout*.”

## 10.3 Layout Planning in Warehouses

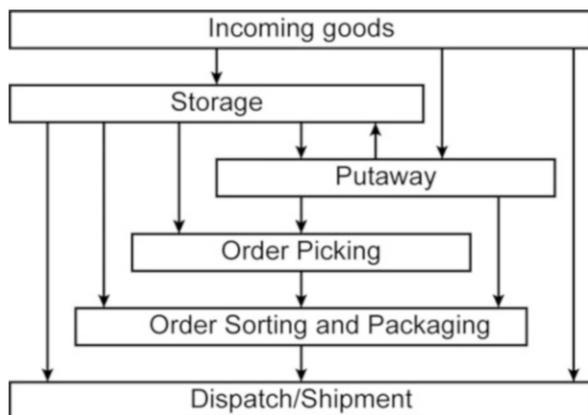
The processes in warehouses can be done manually or be automated. Automation is not always the best option. Automation requires investments in software. Manual process organization can be the more flexible option. However, automation can help in increasing efficiency and reducing lead time.

The basic warehouse processes are represented in Fig. 10.10. Consider these processes in detail.

### 10.3.1 Incoming Area

After the receipt and control of goods in the incoming area, items can be either moved to storage or directly to the outbound area if, e.g., customer orders already exist, or because of a cross-docking principle which means the in-transit merging of different incoming bins to some outgoing bins without intermediate storage.

**Fig. 10.10** Warehouse processes



**Table 10.1** Advantages and shortcomings of storage strategies

Strategy	Advantages	Shortcomings	Applications
Dedicated storage	Item positions are exactly known	Low capacity utilization	Spare part warehouse Workforce fluctuations
Cluster storage/class-based storage	Productivity increase Transportation reduction	Decrease in capacity utilization	Retail warehouses
Random storage	High capacity utilization	Control complexity; investments in IT	Automated high-level warehouse

In many cases, returns are also processed in the incoming area. For example, in the warehouses of E-Commerce retailers, the return rate can be up to 70% of sales.

### 10.3.2 Storage Area

Next, in the storage area, several storage strategies can be applied:

- dedicated storage
- cluster storage and class-based storage
- random storage.

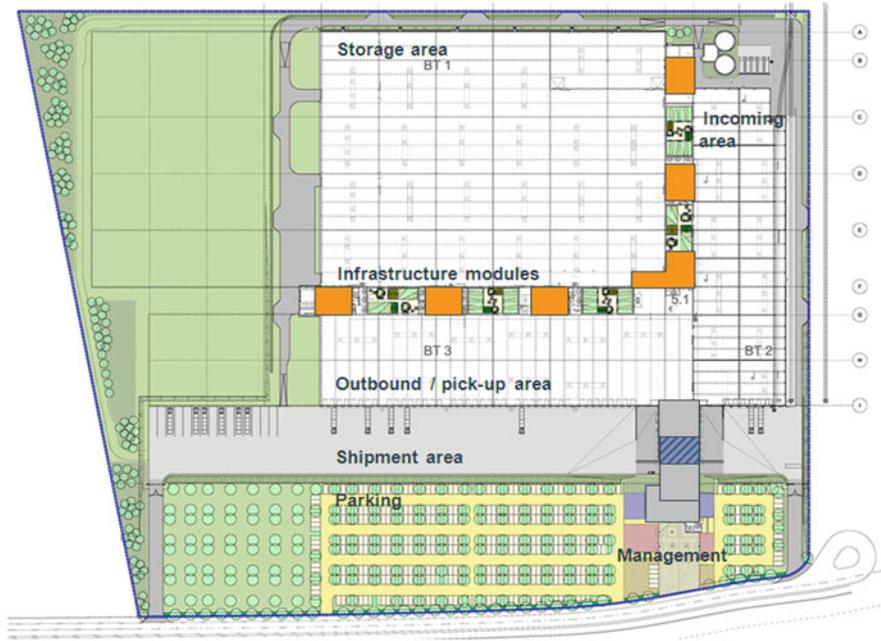
In *dedicated storage*, each item is assigned exactly to a predetermined storage place. *Cluster storage* presumes building some zones for items with common features, e.g., items which are frequently ordered together; or items from the same supplier. *Class-based storage* means that items are stored on the basis of ABC classification (see Chap. 13). In random storage, a chaotic warehouse policy is applied.

The advantages and shortcomings of each strategy are summarized in Table 10.1.

### 10.3.3 Put-Away and Order Pick-Up

FIFO (first-in-first-out) and LIFO (last-in-first-out) are two basic strategies for put-away organization. Two order picking strategies are “man-to-goods” and “goods-to-man.” In the “man-to-goods” strategy, there are several options for picking: Printed pick-up list, Electronic messaging, Pick by Light, Pick by Voice.

It should be noted that even if new technologies like pick by voice present advantages, many logistics managers consider them to have shortcomings from an ergonomic point of view.



**Fig. 10.11** L-shaped layout of a warehouse

### 10.3.4 Layout Concepts

Two layout concepts, straightforward and L-shaped, can be distinguished from one another. In the introductory case study, we considered OTLG distribution center. This company applied the L-shaped layout. In Fig. 10.11, the L-shaped layout of the OTLG warehouse is presented.

Consider another example, the company REWE, which is active in the food retailing industry. Specific for the food retailing industry are the fast processing times for fresh goods. This is why a straightforward layout was selected (Fig. 10.12).

According to this layout, the warehouse is divided into four temperature zones: dry assortment, fruits and vegetables area, fresh meat area ( $0\text{ }^{\circ}\text{C}$ ), and a deep-freeze area ( $-24\text{ }^{\circ}\text{C}$ ). The work in the deep-freeze area is very hard since in the summer the difference between the outside and inside temperatures can be more than  $60\text{ }^{\circ}\text{C}$ . The trucks from the suppliers arrive at the gates and are unloaded. The pallets (mostly plastic pallets for hygiene and weight reasons) are moved to the storage area. The random storage principle is applied to the placement of pallets on the shelves. With the help of lift trucks, the pallets are picked up and delivered to the outbound area. The plastic pallets are used to simplify handling at the stores since they only weigh 6 kg. In addition, heavier items are typically located on the bottom of the pallet while lighter items come on the top. The warehouse operates from Sunday 4:00 am to Saturday 6:00 pm. Since demand constantly increases, automation can reduce the lead time and adjust process capacity.



1: Outbound area 3: Incoming area  
2: Storage area



1: Deep-freezing area  
2: Fresh food area  
3: Fruits and vegetables  
4: Disposal area  
5: Dry assortment area

**Fig. 10.12** Straightforward layout form of a warehouse

About 380 employees in Oranienburg (Germany) ensure the replenishment of REWE supermarkets with about 11,000 SKU (Stock Keeping Units). One hundred trucks deliver products to 330 supermarkets from Sassnitz to Jüterbog daily. This means the optimization of 240 routes daily. With the help of modern software using a scientific methodology for vehicle routing and advanced navigation information technology, 95% capacity utilization for trucks is achieved. In the first half of 2012, 35 million incoming items of freight, which arrived on 958,398 euro-pallets, were processed in the incoming area. Thirty-six million items of freight were delivered to markets. The average inventory in the warehouse is valued at about 30.6 million euros. The inventory turnover for dry assortment is about 12; for fresh meat—2100 (on average, a package of fresh meat is processed at the warehouse within 4 h).

## 10.4 Methods of Layout Planning

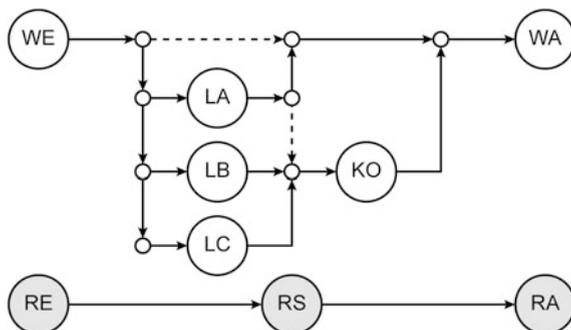
Methods of layout planning can be divided into qualitative and quantitative. In this chapter, we consider the qualitative method “REL-charts” and a quantitative method “quadratic assignment problem.”

### 10.4.1 REL-Charts

#### 10.4.1.1 Problem Statement

REL stands for relationship. With the help of this chart, the activities are illustrated according to their relationship (activity relationship charts, ARC). Now let us consider a specific problem. A layout for a retail warehouse has to be developed with consideration of desirable/undesirable proximity of some areas. The process is presented in Fig. 10.13.

**Fig. 10.13** Warehouse process



The following notations are used:

- WE—incoming and inspection area
- LA, LB, LC—storage areas for A-items, B-items, and C-items respectively
- WA—shipment area
- KO—pick-up area
- RE—receiving area for returns
- RS—storage area for returns
- RA—shipment area for returns

### 10.4.1.2 Solution Method

The REL-chart method is based on the identification of desirable/undesirable proximity relations for each pair of warehouse areas. This identification is subjective and based on expert estimations. In our case, the following REL-chart can be developed (Fig. 10.14).

The following notations are used:

- A—proximity is absolutely mandatory
- E—proximity is very desirable
- I—proximity is important
- O—proximity is possible
- U—proximity is undesirable

For example, the relation between the pick-up area and the shipment area is set up as “A” since these areas are to be located close to each other according to the process flow in Fig. 10.10.

Taking into account the process flow from the problem statement and the developed REL-matrix, the following layout can be suggested (Fig. 10.15).

Note that since REL-chart is a qualitative method based expert estimations, the suggested solution is only one possible option.

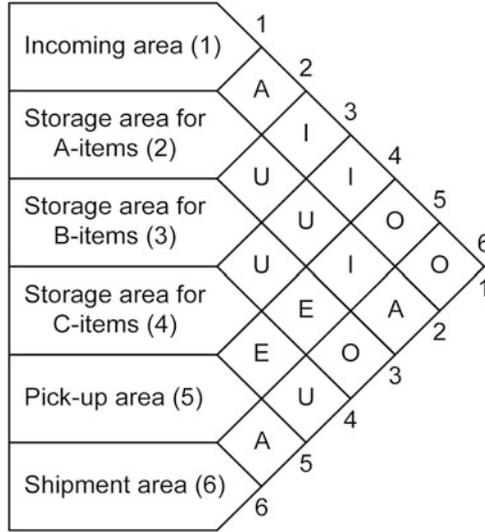


Fig. 10.14 REL-chart matrix

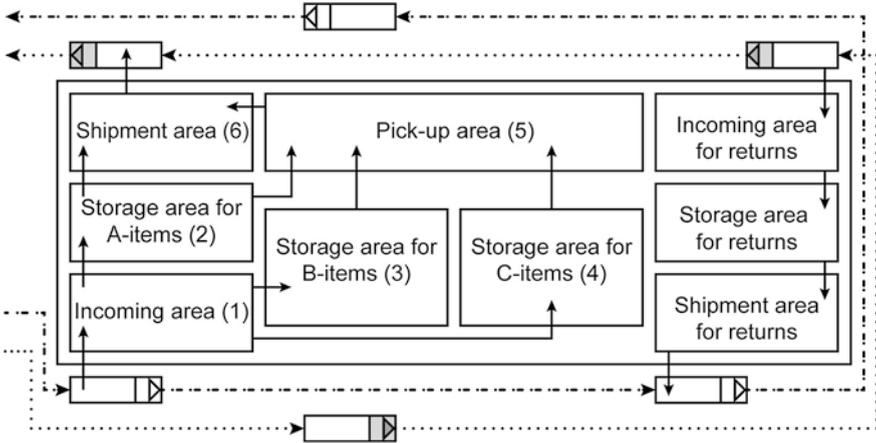


Fig. 10.15 Warehouse layout

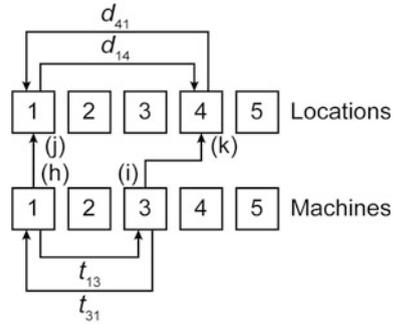
### 10.4.2 Quadratic Assignment Problem

#### 10.4.2.1 Problem Statement

Some machines have to be assigned to some available locations. For each pair of locations, a *distance* is known. Similarly, for each pair of facilities a *material flow* is specified (Fig. 10.16).

Assign machines to locations so that total transportation cost is minimized.

**Fig. 10.16** Problem statement for assignment problem



**10.4.2.2 Model**

Consider the following notations according to Fig. 10.16.

$M = \{M_j, j, k \in M, j, k = (1, \dots, M)\}$  is a set of locations.

$N = \{N_h, h, i \in N, h, i = (1, \dots, N)\}$  is a set of machines.

$d_{j,k}$  is a distance between two locations.

$t_{h,i}$  is material flow intensity between two machines.

Assume that transportation costs are linear and therefore proportional to  $d_{j,k} \times t_{h,i}$  for the assignment  $h \rightarrow j$  and  $i \rightarrow k$ .

We introduce an auxiliary variable  $x_{hj}$  which is equal to 1 if the  $h$ -machine is assigned to the  $j$ -location and  $x_{hj} = 0$  otherwise. Then the model can be defined in the following way:

*Objective function*

$$F(x) = \sum_{h=1}^P \sum_{\substack{i=1, \\ i \neq h}}^P \sum_{j=1}^P \sum_{\substack{k=1, \\ k \neq j}}^P t_{hi} \dot{c}_{jk} \dot{c}_{hj} \dot{c}_{ik} \Rightarrow \text{Min!} \tag{10.1}$$

*Constraints*

$$\sum_{j=1}^P x_{hj} = 1 \quad \sum_{h=1}^P x_{hj} = 1 \tag{10.2}$$

$$x_{hi} \in \{0, 1\} \tag{10.3}$$

Constraints (10.2) dictate that each machine should be assigned to only one location. Constraint (10.3) dictates that auxiliary variable  $x_{hj}$  is a Boolean variable. In reality, additional constraints of a technological and technical nature may exist which are difficult to formalize.

**10.4.2.3 Model Analysis and Solution Methods**

The model (10.1, 10.2 and 10.3) is a linear integer programming model. Such a class of model is NP-hard. This means the optimal solution for reasonable problem size

and in reasonable time is difficult to obtain with the help of classical methods for solving such problems (e.g., branch & bound). This is why different heuristics are used in practice for such solutions.

### **10.4.3 Simulation: Modeling Operations at Pharmaceutical Distribution Warehouses with AnyLogic**

#### **Problem Description**

Cardinal Health, a billion dollar pharmaceutical distribution and logistics firm, manages multiple products, from brand name pharmaceuticals and generic drugs to over the counter drugs, health and beauty items, as well as their own private label. They face a multitude of typical distribution warehouse challenges that are further complicated by the nature of pharmaceutical products, which are smaller in size, consumable, expensive, and possibly life critical. Cardinal Health is an essential link in the healthcare SC, offering next day delivery to over 30,000 locations including hospitals, retail pharmacies, physicians' offices, and direct to consumer.

Other value added services include efficiency and demand management, working capital management and contract credit management. These services along with poor manufacturing reliability and supply disruptions in the market due to Food and Drug Administration (FDA) and Disability Discrimination Act (DDA) regulations add complexity to decision making. Cardinal Health must keep up with the variability in pharmaceutical distribution management. Cardinal Health must consider facility layout, flow of product, order picking, labor planning and scheduling, customer order requirements, and day-to-day operations management.

#### **Model Development**

Traditional analysis tools, such as empirical trial and error, are risky, expensive and difficult to use for making changes. Industrial engineering and operations researchers suggested mathematical models which were inexpensive, but did not capture unexpected dynamics. If anything is open or has emergent behaviors, such as congestion, a standard mathematical model is unable to solve the problem. Process driven or discrete event modeling was not advantageous because of its inability to represent a facility naturally. This led Brian Heath (Director of Advanced Analytics at Cardinal Health) and Cardinal Health to explore alternative analysis options. Agent Based Modeling (ABM) with AnyLogic Simulation and Modeling software gave Cardinal Health the tools required to tackle many distribution warehouse issues without the restrictions of traditional tools.

#### **Solution Development**

ABM represents the abstraction of distributed autonomous entities that can interact with each other and their environment through space and time, allowing Cardinal Health to capture work time allocation, congestion waiting time, cycle times, distance traveled, worker variability and other important metrics.

### Testing the Solution

The model built was ultimately concerned with the activities of employees and their interaction with each other during the day, making it necessary to import data such as picking time and performance standards into the model.

### Analyzing the Results

Cardinal Health could gather congestion waiting time data and see how much of a problem it was causing in the warehouse since “agents” were modelled as individuals with special relationships to each other. Additional parameters included in the model were several worker speeds, worker behavior, learning curves, cycle times, product turn-around, and distance covered walking or driving. The ability to import Excel files was also imperative as Cardinal Health has numerous warehouses, and it is mandatory to test multiple layouts. Using AnyLogic, a change is as simple as updating the Excel file, importing it into the model and running the model again.

### Implementation

The ABM built with AnyLogic software allowed Cardinal Health to compare layouts, picking technology, and product slotting strategies. In addition, they could evaluate different methods of picking to update staffing models and for on-the-floor support if a workload changed, as orders vary on a day-to-day basis. Statistics were also gathered, such as takt time, how many batches are completed in an hour, truck unloading time, and sequencing of events. Despite the clarity provided by the above metrics, the model revealed a problem because of the random distribution of work. Employees’ workloads were uneven, with one being faster and one slower. By balancing the workload, employees began working at a similar pace and congestion decreased dramatically. By minimizing congestion using AnyLogic software, Cardinal Health was able to decrease the average shift length from 10.5 to 7.25 h and increased employee capacity. Cardinal Health saves over \$3 million annually using ABM with AnyLogic Simulation technology. “AnyLogic’s agent libraries, flexible architecture, and integrated animation enables the continuing success of this project,” declared Brian Heath, Director of Advanced Analytics at Cardinal Health. You can view his presentation and learn more about using ABM in real world application.

---

## 10.5 Key Points

A layout is the physical arrangement of objects in a space. Fundamental objectives of layout planning are cost minimization for internal transportation, lead time reduction, or reasonable arrangement of departments in facilities. In addition, layout planning can be used to reduce the risk of good damages because of accidents in the warehouse, e.g., a fire.

In general, there are four basic types of layouts in manufacturing:

- fixed position layout
- process flow layout

- product flow layout
- cell-based layout.

These forms of layouts depend on the process flow design. In warehouses the layout is determined by the process flow, which includes the following stages:

- incoming and inspection area
- storage area
- put-away area
- pick-up area
- packing area
- shipment area.

Methods of layout planning can be divided into qualitative and quantitative. We considered a qualitative method “REL-charts” and a quantitative method “quadratic assignment problem.” REL-charts can be applied to cases where considerations of desirable/undesirable proximity of some areas are important. The quadratic assignment problem is an optimization method for optimal layout planning with the objective of minimizing total transportation costs.

---

## 10.6 Discussion

In our examples, production facilities were described (e.g., the creation of brake systems) or the layout of retail warehouses for distribution centers for spare parts and food retailing. Please discuss how the layout planning consideration might be transferred to layout problems in the following cases:

- offices in an insurance company
- departments at your local authorities
- structure of supermarkets or shopping malls
- organisation of functional areas at hospitals or clinics.

What do you think are the relevant criteria which influence decisions on these layouts?

### Acknowledgments

**Introductory Case-Study “OTLG Ludwigsfelde”** The authors thanks the OTLG GmbH & Co. KG for the permission to use the company materials in this textbook.

**Layout Planning in Warehouses** The authors thank the logistics direction of REWE East for the permission to use the company data in this case-study.

**Layout Examples in Production** The authors thank the *Knorr-Bremse Berlin Systeme für Schienenfahrzeuge GmbH* for the permission to use the company materials in this textbook.

## Bibliography

- Bicheno J (2004) *The new lean toolbox*. PICSIE Books, Buckingham
- Brunner FJ (2011) *Japanische Erfolgsrezepte*. Hanser, München
- Dolgui A, Proth J-M (2010) *Supply chain engineering: useful methods and techniques*. Springer, Berlin
- Gogate AS, Pande SS (2008) Intelligent layout planning for rapid prototyping. *Int J Prod Res* 46 (20):5607–5631
- Günther H-O, Tempelmeier H (2012) *Produktion und Logistik*, 9th edn. Springer, Heidelberg
- Heizer J, Render B (2013) *Operations management: sustainability and supply chain management*, 11th edn. Pearson, Harlow
- Ioannou G (2006) Time-phased creation of hybrid manufacturing systems. *Int J Prod Econ* 102 (2):183–198
- Martin JW (2007) *Lean six sigma for supply chain management – the 10-step solution process*. McGraw Hill, New York
- Nee AYC, Ong SK, Chryssolouris G, Mourtzis D (2012) Augmented reality applications in design and manufacturing. *CIRP Ann Manuf Technol* 61(2):657–679
- Okulicz K (2004) Virtual reality-based approach to manufacturing process planning. *Int J Prod Res* 42(17):3493–3504
- Saad SM, Lassila AM (2004) Layout design in fractal organizations. *Int J Prod Res* 42 (17):3529–3550
- Schenk M, Wirth S, Müller E (2014) *Fabrikplanung und Fabrikbetrieb. Methoden für die wandlungsfähige, vernetzte und ressourceneffiziente Fabrik*, 2nd edn. Springer, Berlin
- Schonberger RJ (2008) *Best practices in lean six sigma process improvement – a deeper look*. Wiley, Hoboken, NJ
- Slack N, Chambers S, Johnston R (2010) *Operations management*, 6th edn. Pearson, Harlow