As counterbalanced trucks always carry their loads outside the chassis area they can accommodate a large range of items although the size should not be excessive. They are useful as general purpose machines and are employed in most branches of trade and industry.

In some instances more specialized trucks or equipment may be superior. A counterbalanced truck is large and heavy compared with other truck types of equivalent lifting capacity. It takes up more space and may possibly be uncompetitive with a reach truck in operations involving indoor stacking in pallet racks. Its weight and size may also make it slower and less manoeuvrable than other, smaller truck types.
Pedestrian and ride-on pallet base stackers

Powered stackers are divided into four different basic types depending on the operator's position.

Pedestrian powered stacker.

Stand-on powered stacker with fold-down platform.

Ride-on powered stacker with a standing driver.

Ride-on powered stacker with a seated driver.
Order pickers

Order picking refers to retrieval of individual items from storage and normally involves taking goods from one unit load and adding it to another. There are three basic methods.

Station picking. The goods come to the operative, for instance, on a roller conveyor. The work station is fixed.

Low level picking. The operative works up to a height of 2.5 metres.

High level picking. The operative is elevated, for instance, with the truck and can thus reach higher storage levels.

Low and high level order picking may involve the use of a number of different truck types.

**Low level picking**

- Hand pallet truck.
- Pedestrian pallet truck.
- Low-lift order picker.

**High level picking**

- Driver-elevating order picker.
- High-lift order picker.
An overhead travelling crane consists essentially of a bridge constructed from one or several girders supporting a mobile hoist. End carriages drive the bridge along rails on two high level gantries.

Indoors, the rails may be mounted on pillars or suspended from roof supports.
Design

Overhead travelling cranes are either top mounted or underslung. In underslung designs, the end carriages 'hang' on a roof mounted I-beam. Top mounted cranes run on girders or rails supported by pillars (see pictures).

For heavier loads top mounted cranes are the most commonly used. They come in standard versions with capacities of 2–50 tonnes and in custom-built versions up to 500 tonnes. Single or double girder structures are available, the former being sufficient for loads weighing up to approximately 10 tonnes, the latter being used for heavier loads.

Overhead travelling cranes usually have three main drive mechanisms for:
- Lifting.
- Crane travel.
- Hoist trolley travel.

Underslung cranes weigh less and require less headroom than top mounted cranes; they also permit better space utilization. Pillars are not needed and the hoist trolley can utilize the entire span of the crane and even change over to another crane.

However, the lifting capacity is limited by the strength of the roof. As a result, underslung cranes are normally available with capacities of 5 or 6 tonnes, occasionally 10 tonnes.

For lighter loads (up to 1,000 kg) simple crane kits are available. They incorporate chain hoist blocks and, since they are usually not equipped with a motorized trolley, horizontal travel is manual.
Single girder cranes normally feature a wire rope hoist block mounted on an underslung trolley running on the bottom flange of the crane bridge. Double girder crane bridges have hoist trolleys which run along the tops of both beams. The beams are usually in the form of steel box fabrications.

The crane travel mechanism propels the entire assembly on girders or rails. The hoist trolley has its own travel drive.

The efficiency, speed and reliability of overhead travelling cranes depend to a great extent on the parallelism of the travel rails and the synchronicity between the end carriage motors.

The power units for both travel and lifting operations are usually electric motors. Hydraulic and pneumatic motors are also used for lifting and may provide control advantages.

However, electric motors are continually being developed for improved power-to-weight ratios and better control characteristics. Some electric drives, for example, can be reversed without first being brought to a halt, a facility which makes for considerably quicker and more flexible handling.

Cranes for lightweight applications are usually operated from floor level by means of a pendant control (see picture). On heavier cranes, for instance, handling steel, cabs (fixed or designed to move with the crane) are more common.
System design

When installing an overhead travelling crane, it should be regarded as an integral part of the building. The drawing below indicates various dimensions and load points which may be of importance and which determine crane capacity, reach and lifting range. (The example refers to an underslung crane.)

In addition to the usual lifting hook, cranes can be fitted with a range of alternative attachments, for example, tongs, clamps, grippers and magnets (see figures).
Application examples

The photographs below show examples of overhead travelling crane applications.

Manual overhead travelling crane.

Top mounted overhead travelling crane with telescopic clamp for paper reels.

Underslung double girder overhead travelling crane with cab and extendable loading device for lengthy loads.

Top mounted overhead travelling crane handling piping and tubing. The floor area is well utilized, but not the potential volume.

40 tonne rail mounted double girder overhead travelling crane for foundry work.
Gantry cranes (or Goliath cranes) are supported on legs with wheels that run on rails or on the ground. A hoist trolley traverses the main girder. The hoist mechanism may be installed in the trolley or inside the gantry structure.
Roller conveyors are line restricted devices and consist of rollers mounted between two side members. Bearings are usually incorporated in the rollers to cut down mechanical losses.

Side members may be mounted on height adjustable supporting frames or directly on the floor.
Belt conveyor designs usually resemble the one illustrated. The goods carrying belt is driven by an electric motor through a worm gear unit and a drum. The drum may be coated with an anti-slip formulation for improved driving characteristics and is often laterally curved to ensure belt self-centering. The belt passes over idlers which support and also guide the belt. Idler distances depend on the weight of goods for which the conveyor was designed. For lightweight goods (max. 40 kg) idlers may be replaced by a slider plate. Sometimes the plate is complemented by a few idlers permitting conveyor lengths up to 80 metres with low loads.

The drive system described makes great demands on space at the end of the line. As an alternative, it may be located centrally under the conveyor (see figure) although this is more complicated and consequently more expensive.

To prevent slip between belt and drive drum, the belt must be tensioned—automatically or with a hand operated tensioner.

An automatic tensioner may consist of a counter-weight connected to a guide drum. Exact tension is maintained even if the belt stretches.

Short conveyors have a fixed tensioning arrangement (see picture) in which the position of the return drum is adjusted with handwheel screws.
System design

Changes from inclined to horizontal conveyor movement should be gradual and smooth and should be completed before the next, horizontal conveyor section takes over.

Where conveyors run at different levels, goods flows can be merged via a simple slide.

In changes from horizontal to inclined movement the junction must occur where the horizontal movement ends. In this case changeover is less smooth.

A third method of merging flows is with traffic controllers.

For purely horizontal changes of direction, the belt is supported on tapered rollers throughout special curved sections. Relatively small radii (only slightly larger than belt width) are possible.

The simplest way of merging different goods flows is by angled transfer round a rotating pivot.
'Overhead conveyors' describes all conveyors with roof-mounted drives. Literally speaking, loads can be transported by carriers running on rails suspended from the roof or carried on the floor by vehicles with roof-level drives.
Overhead conveyors may be divided into three main types, depending on the drive method (see figure). The usual method is by chain. Worm drives and self-powered carriers are two other options.

Chain operated overhead conveyors come in two main designs: continuous direct drive or with a disengaging feature via a separate chain fitted with drive dogs (power-and-free type) to facilitate accumulation, switching, etc.

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**Classification of overhead conveyors.**

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**Application**

Overhead conveyors provide a fixed handling installation that leaves the floor completely free for personnel and vehicle traffic. Great freedom of layout is possible. Both vertical and horizontal bends are easily constructed. Lines can accommodate the obstacles encountered in a non-purpose-designed building.

Overhead conveyors are often comparatively cheap and simple. Because of their favourable weight/handling capacity ratio, overhead conveyors can often provide both a comparatively inexpensive and simple solution to a handling problem. Capacities can be adjusted by allowing several carriers to handle a load. An overhead conveyor designed for 100 kg items is able to handle loads up to 400 kg suspended from spreader attachments. Another advantage — extensively used in factories — is the simplicity of accumulation.

On the negative side, an installation may limit the usable free headroom. This could be critical in warehouses with high lift fork trucks. The load bearing capacity of the roof also becomes important; if reinforcement is necessary, considerable extra costs may be involved.

The most extensive use of overhead conveyors is in industry, particularly in assembly operations where both basic assemblies and components are moved in a way that leaves the floor area free for traffic, etc.

For certain operations such as paint spraying and coating, overhead conveyors are the only possible method. Blasting and enamelling installations also employ overhead conveyors to overcome difficult operating conditions.

Goods terminals (for combined rail/road operations as well as for road vehicles alone) use overhead conveyors for internal transport and for sorting mixed general cargo. In these cases, hand pallet trucks are towed along the floor by suspended hooks. The mixed handing (by manual means, hand pallet and other trucks) at these terminals demands floor areas free from obstacles, and overhead conveyors are the only realistic solution.
Warehouses and stores can use overhead conveyors both for input and output, e.g., between shelving. The advantage is that they do not hinder trolleys, trucks and personnel in the aisles.

Pick-and-place installations are now tending to be supplied with packing materials by overhead conveyor. Generally speaking this solution creates the least disturbance for other handling arrangements. Occasionally, this requirement is entirely forgotten at the planning stage; an overhead conveyor is then a convenient answer.

In addition to mixed cargo and assembly operations there are also several types of installation in which the loads themselves are more naturally transported and stored in a suspended position, e.g., clothing, animal carcasses. Development in such areas is towards transport and handling lines which use overhead conveyors wherever possible.

![Overhead conveyor for clothes on hangers.](image)

<table>
<thead>
<tr>
<th>Summary of overhead conveyor characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advantages</td>
</tr>
<tr>
<td>Free floor area</td>
</tr>
<tr>
<td>Layout simplicity (vertical and horizontal bends)</td>
</tr>
<tr>
<td>Simple design</td>
</tr>
<tr>
<td>Low investment</td>
</tr>
<tr>
<td>Accumulation possible (power-and-free)</td>
</tr>
</tbody>
</table>

### Design

The figure shows the design principles of a chain operated overhead conveyor. Loads are suspended from wheel-mounted load carriers which are moved on a rail by a chain. In this case, the chain is beneath the rail.

A complete conveyor installation may incorporate the following components:

![Conveyor components](image)
Rails and chains come in many different designs.

Suspension attachments can always be adapted to the type of goods carried. Many versions exist. Their design may be influenced by the need to load and unload, and to switch or rotate the loads.

Various rail/chain designs. A, B and C represent alternatives with carriers mounted on external rail surfaces. In D and E both carrier and chain run inside the rail.

Chains which operate inside the rail normally have designs which permit horizontal and vertical articulation, together with runners which provide a type of bowing action.

Floor trolleys are used in, among other places, mixed cargo terminals.

Bowing chain.

This is the simplest design to install. It also protects carrier wheels and bearings.

Load carriers with shelves.
Articulated suspension attachments facilitate vertical handling.

Conveyed objects may require rotating, for instance, in spray painting. Special attachments are available for this.

These are a few examples:

- Load carrier consisting of a two-tine fork.
- Automatic rotating attachment: fixed positions.
- Finger hook.
- Automatic rotating attachment: infinitely variable positions.
Power-and-free conveyors offer simplified accumulation and switching and can also be used when the route involves a brief descent to a local level.

They are commonly applied in the manufacturing industry although, latterly, self-powered overhead monorail systems (see below) have become more competitive because of the greater flexibility inherent in individual drive systems.

To save drive chain costs, power-and-free conveyor systems can be designed so that an inclined bottom rail (2–3 per cent) in some sections moves the trolleys. The technique is used for accumulation. Note, however, that the carriers may gather considerable speed; only robust goods (such as sacks) should therefore be conveyed in this way.

If individual goods items have to be released, for example, in connection with accumulation or switching, two running rails are used. The continuously moving drive chain runs on the top rail, while the bottom rail accommodates separate carriers driven by pusher dogs. The name 'power-and-free' thus refers to the release facility.

Of the two release methods, the simpler uses spring-loaded followers. When a carrier is stopped by a stationary carrier ahead, the spring-loaded follower gives way to let the drive chain pusher dog pass. This simple and inexpensive accumulation is limited, however, by the fact that maximumtractive power is determined by the spring strength of the follower, making inclined or vertical handling difficult.

A more complex but quite commonly used method is based on mechanical release of a vertically operating follower (in a so-called proximity carrier).

Combination of powered and unpowered sections in a power-and-free overhead conveyor.

Power-and-free conveyor.

The figure shows a version where a carrier in front releases an approaching carrier by forcing its projecting release handle upwards. Note that the total length of the carrier must always be greater than that of the loads handled.
Worm operated overhead conveyors

Substituting a worm for a chain results in an ingeniously simple overhead conveyor. Loads can be suspended on hooks mating with the worm thread. Among drawbacks are comparatively low speed and mechanical wear of the worm, especially if heavy loads are carried.

A similar function is achieved if, instead of a worm, a rotating tube is used and goods are suspended from carriers running on skewed wheels. (Cf. the Car-Trac system described in section ‘Rail mounted trolleys, trucks and tractors’.) The design is used, for example, for moving clothes on hangers.

Self-powered overhead monorail conveyors

Self-powered overhead monorail conveyors have carriers with built-in electric motors instead of chain, worm or rotating tube drives.

Self-propelled carriers can run inside girder structures (as shown in figure). In this case power unit, load carrier and control electronics form a single assembly. Power supply is through contact between a current pick-up on the carrier and a conductor rail inside the girders. This design facilitates routing and control of individual carriers. (See section ‘General information on line restricted materials handling equipment’.) Track systems and switching are simpler.

On the other hand, individual carriers are more expensive and more complex, although this may not prevent a system with even a moderately large number of carriers from ultimately emerging as a less costly solution.

Self-powered overhead monorail conveyors can also be designed to run externally on girders. They are then more accessible for servicing and can, as shown in the figure, be constructed from a power supply and propulsion and control modules.
Lifts and elevators handle goods vertically (this excludes inclined conveyors) and may be divided into four main types:

**Lifts (intermittent operation)** have load-carrying cages or platforms which move up and down in vertical shafts or in frames with steel guideways.

**Lifting platforms (scissor lifts)** are raised and lowered mechanically on the scissor legs principle.

**Paternosters (continuous operation)** have several load-carrying units that move continuously or intermittently in an endless loop.

**Platformless elevators** have no individual load-carrying structures but allow random use. (Loads are moved by clamping or positive pressure.)

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**Application**

Lifts/elevators move goods between different levels, e.g., between conveyors at different heights or between storeys in warehouses and terminals. They can also bridge differences in levels which occur between new and old parts of an installation or between loading bay and ground level.

The same tasks may be performed by inclined (belt or slat) conveyors. Compared with them elevators require considerably less space but throughputs are normally reduced. For heavy and/or bulky loads lifts/elevators may be the only realistic solution.

Where sufficient space is available without an increase in costs, an inclined belt or slat conveyor is normally the cheapest and most efficient method of handling large flows of light or medium goods. Space and/or layouts are often decisive factors in choosing a lift/elevator.

Capacity and price vary greatly, i.e., from 10 kg for the smallest pneumatic elevator to 60 tons for the largest lift platforms, and from SEK 5,000 for the simplest lift platforms up to about one hundred times as much for a high capacity pallet elevator (1980).
Lifts consist of a frame, platform or cage, hoist and enclosure.

There are many versions, from light duty models intended to lift light cardboard and wooden boxes to fully automatic equipment for pallet loads weighing up to several tonnes.

The frame may be a simple mast to one side of the platform or may have four corner posts which enclose the platform.

Loading/unloading may be manual or semi- or fully automatic. The platform may be equipped with a roller table, chain or belt conveyor.

Loading/unloading configurations may usually be chosen according to the alternatives shown in the figure.

Loading/unloading sequences and vertical movements can be monitored by photoelectric cells and limit switches. Gates should be protected by wire mesh or automatically operated doors.

Power sources are either electric or hydraulic.

The illustrations show some alternative operating methods.
An electric hoist raises or lowers the lift cage via chains, steel cables or rack and pinion.

Chains are used primarily for slow speeds and loads up to 20 kg. Heavier duty, faster lifts employ an electric motor and cable hoist drum, an arrangement which needs space above to accommodate the hoist equipment and counterweights. Hydraulic drives usually require space for the hydraulic rams under the platform. On the other hand, motor and pump may then be positioned up to 30 metres away from the hoist — an advantage in terms of space utilization.

Rack and pinion drives may be advantageous for temporary installations (e.g., in building work, etc.) as drive unit and cage may then be of integral design.

For speeds of less than 1 m/sec, A.C. motors linked to worm or plain gear reduction units are used, although positional accuracy at stops can impose limitations. Acceptable positioning demands approach speeds not in excess of 0.2 m/sec. This requirement, together with the need for high hoist speeds, is met by using motors with 1:2 and 1:6 speed ratios.

For very great lift heights, more advanced equipment is necessary, for instance, a Ward Leonard unit of the type used in passenger lifts.

Unlike lifts, paternosters have a number of platforms or cages fixed to endless chains, etc. Operation is normally continuous. Loading/unloading (possibly automatic) occurs while the unit is running, resulting in greater throughput than with lifts plus a more even flow of goods.

**Pallet elevators** are a modified version of paternosters.
Platforms consist of battens which form rigid horizontal surfaces in one direction of travel but behave like a roll-top during the return. This design saves space, is simple and offers high throughputs. Above all it is used for pallet transport between different levels. There are also special platforms for drums, bottles, paper reels, etc. Typical capacities are 8–16 pallets per minute, a figure which is reduced to 3–6 pallets per minute for pallets over 1,000 kg in weight.

*Suspended tray conveyors* have freely swinging platforms suspended from two parallel chains, permitting both vertical and horizontal transport.

*Suspended tray conveyors can offer both horizontal and vertical transport.*
Platformless elevators

Mechanical platformless elevators are relatively new and were developed originally for vertical handling of mailbags and luggage at airports. The load is held between two belts either by the belts' elasticity or by using an inflated air bag.

Both types are suitable for light general cargo. The former has the advantage in that it adapts its shape to the load and can therefore accommodate varying shapes and sizes. It is used only for lifting; lowering is via slideways or chutes.

In pneumatic elevators goods are moved through a tube by a difference in air pressure acting on their top and bottom surfaces. This method assumes uniform goods with plain sides which fit the tube.

Lifting platforms (scissor lifts)

Lifting platforms are comparatively simple and versatile devices to bridge height differences from a few decimeters up to several metres.

They are slow compared with other elevators and are best suited to infrequent handling operations. They can be used instead of a bay for loading/unloading lorries, adjusting precisely to various deck heights. They are also used to move trucks from ground to bay level or between different levels which may be the result of extensions to old buildings.

Lately, lifting platforms equipped with traction motors and with wheels running on floor-level rails have been developed as order pickers in warehouses for lengthy goods (carpets, tubing, bars). They may then be an interesting alternative to more costly stacker cranes or to conventional warehouses designed for forklift or crane operations.

Lifting platforms are also extensively used in production, e.g., to feed or receive items from plant or to obtain proper working positions (as work tables, work platforms).

A lifting platform consists of a base frame and a top platform which is raised and lowered by one or several hydraulically operated scissor legs (see figure above).
Standard platforms are manufactured in three sizes. Single scissor-leg platforms are the most usual and are available in capacities of 500 kg—30 tonnes. Double scissor-leg (vertically positional) platforms are used for great lift heights (2—5 m). Double scissor-leg (horizontally positional) platforms are used for lengthy goods and vehicles.

Lifting platforms may be supplemented by roller or wheel conveyors for simpler loading/unloading, e.g., in connection with feeding plant. They may also be mobile, with rubber wheels, rail-mounted wheels or air cushions.

**Application examples**

Pallet input to a high-level warehouse. Pallets are received and inspected on floor-mounted roller conveyors. A pallet elevator then lifts them to accumulating roller conveyors for transfer to high-level storage. Elevators were chosen to give the most economical utilization of available space.

When loading or unloading, a lifting platform may be used as a complete substitute for a loading bay. Lorry heights — varying from 0.8—1.6 m — are then immaterial but the work may take a little longer.
A manually operated crane in a high-level warehouse where the picker transfers goods from shelves to a paternoster which feeds a packing station via a belt conveyor.

A lifting platform may also permit an existing loading bay to accommodate various lorry heights without the use of ramps – an aid often necessary with conventional bays.

Steel bars in this warehouse are removed by hand but operations are facilitated with a double scissor-leg lifting platform equipped with traction motor and wheels running on rails (lift height is 2 m and travel speed 0.3 m/sec).

<table>
<thead>
<tr>
<th>Elevator type</th>
<th>Item weight kg</th>
<th>Number of items per min</th>
<th>Lift height m</th>
<th>Lifting speed m/min</th>
<th>Power source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lift with cable hoist</td>
<td>50–2,000</td>
<td>1–3</td>
<td>Unlimited</td>
<td>12–24</td>
<td>El. motor</td>
</tr>
<tr>
<td>Pallet elevator</td>
<td>500–1,500</td>
<td>5–20</td>
<td>Unlimited</td>
<td>12–20</td>
<td>El. motor</td>
</tr>
<tr>
<td>Standard lifting platform, single scissor-legs</td>
<td>500–30,000</td>
<td>See lift speed</td>
<td>0.8–2.0</td>
<td>0.5–4</td>
<td>Electro-hydraulics</td>
</tr>
<tr>
<td>Lifting platform double scissor-legs (vertically positional)</td>
<td>750–8,000</td>
<td>See lift speed</td>
<td>1.5–5.0</td>
<td>2–4</td>
<td>Electro-hydraulics</td>
</tr>
</tbody>
</table>