

Coordination in transportation process

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- The transport process consists of different, connected activities. Their number and characteristics depend on the specific working conditions of the vehicle fleet. One general condition for the efficiency of these processes is their mutual alignment and the coordinated functioning of different technological elements. A significant part of the vehicle operating time is spent on loading and unloading operations. Because of this, it has a strong effect on vehicle performance, that is, on their productivity. For this reason, important technological elements of the transport process are the loading and unloading points, as well as the time vehicles spend at these locations. Therefore, in the organization of transport processes, it is important to understand the factors that influence the length of this time.
- As terminal points in the movement of freight, loading and unloading locations (stations) can be placed within logistics centers of different sizes and functions, public warehouses, industrial complexes, terminals of specific transport modes, and similar facilities. In other words, terminal points are located where particular goods and the vehicles that transport them begin and end their routes.
- Places where loading and unloading operations are carried out can, in general, be called terminals or freight terminals.

Terminal locations and their characteristics

The functions of freight terminals relate to different freight handling operations, which support loading and/or unloading and the execution of transport processes. The technologies used in their operation vary. However, they all share the goal of performing loading and unloading as efficiently as possible.

This means that terminals provide::

- loading and unloading of freight,
- receipt and dispatch of freight,
- preparation and processing of freight, and temporary holding of freight,
- storage, preparation of documentation, etc.

Terminal locations and their characteristics

One of the key technological elements of every freight terminal is the loading and unloading area and the related operating spaces (fronts).

Their size and forms of organization depend on various factors, such as: the way vehicles are positioned; the size and maneuvering characteristics of vehicles; the number of vehicle positions; the layout and size of other facilities and their areas; the location of loading and unloading areas; the available space and its dimensions, etc. Based on this, key characteristics of a terminal location can be identified, which influence the coordination and synchronization of activities in the transport process.

Supply chain 2

Vehicle positioning

Vehicle positioning, that is, the position of the vehicle's longitudinal axis relative to the loading/unloading front (line), can be parallel, perpendicular, or angled (oblique).

- The characteristics of parallel vehicle positioning are: a relatively large loading/unloading front length; a relatively small aisle width; simple vehicle maneuvering; and access to the vehicle cargo area from one (long) side.
- Perpendicular vehicle positioning is characterized by access to the vehicle cargo area only from the rear (short) side, a relatively small front length, and a relatively large aisle width.
- Angled (oblique) vehicle positioning can be organized at different angles. It is characterized by access to the vehicle cargo area from both the side and the rear, while the length of the loading front and the required aisle width depend on the positioning angle

Throughput capacity

The throughput capacity (throughput capability) of a terminal location is defined by the amount of freight (most often expressed in tons) that can be loaded and/or unloaded within one hour. Accordingly, the determination of the throughput capacity of a terminal location (Q_h) can be calculated using the following formula.

Here, the symbol $X_{u(i)}$ represents the i -th number of loading/unloading positions for freight, while the symbol $\tau_{u(i)}$ denotes the time required for loading/unloading a unit of freight, expressed in tons, at the i -th loading/unloading position.

$$Q_h = \frac{X_{u(i)}}{\tau_{u(i)}} (t/h)$$

Throughput capacity

If the service time for one vehicle ($t_{u(i)}$) is known, the throughput capacity can also be expressed as the number of vehicles that can be served (loaded/unloaded) per unit of time (Ah), as shown in the following relation.

$$A_h = \frac{X_{u(i)}}{q \cdot \gamma \cdot \tau_{u(i)}} = \frac{X_{u(i)}}{t_{u(i)}} \text{ (vozila/h)}$$

Operating rhythm

The operating rhythm of a terminal location ($R_{u(i)}$) is defined as the average time required to serve (load/unload) one vehicle. It represents the average time interval between two vehicles leaving the loading/unloading position. Thus, the operating rhythm is given by the following relation. It can be observed that the operating rhythm of a terminal location is the reciprocal value of its throughput capacity.

$$R_{u(i)} = \frac{q \cdot \gamma \cdot \tau_{u(i)}}{X_{u(i)}} = \frac{t_{u(i)}}{X_{u(i)}} \text{ (h/voz)}$$

Coordination of vehicle operations and terminal stations

The coordination of a loading/unloading station and the vehicles it serves, under conditions of a defined transport route (relation), is an important factor for maximizing the productivity of transport and loading/unloading capacities. In other words, the throughput capacity of a terminal location should be such that it ensures both continuous operation of the terminal itself and continuous servicing of vehicles.

A condition for such operation is the alignment between the operating rhythm of the loading/unloading station and the arrival (movement) interval of the vehicles served by the station. This means that the operating rhythm, i.e., the time between the departure of two consecutive vehicles from the terminal location ($R_{u(i)}$), should be equal to the vehicle movement interval (I_w), as shown in the following relation.

$$R_{u(i)} = I_w$$

Coordination of vehicle operations and terminal stations

Disruptions in the coordination between vehicle operations and terminal systems can occur due to various delays and time losses. In such cases, queues of vehicles may form at the entrance to the terminal, or the loading/unloading station may have unused capacity related to handling equipment. If the operating rhythm of the station is greater than the vehicle arrival interval, i.e. $Ru(i) > Iw$, vehicles will wait in a queue for service. If the opposite is true, i.e. $Ru(i) < Iw$, idle time of the loading/unloading equipment occurs.

The occurrence of idle time in the loading/unloading station allows for an increase in the number of vehicles, i.e. a reduction in the arrival interval (an increase in frequency) of vehicles for service. Vehicle queues in front of the station can be eliminated by increasing the intensity of loading/unloading equipment operation or by reducing the number of engaged vehicles. In general, a complex analysis is required, taking into account a range of performance indicators of both the vehicle fleet and the terminal location.

Coordination of tractor units and semi-trailers

In the use of road trains consisting of tractor units and semi-trailers (road train type $T + (m)Ps$), different approaches can be applied in the organization of transport processes. Three cases can be identified:

- Treatment of $T + (m)Ps$ as a single unit (complete set),
- Separate treatment of the tractor unit (T) and the semi-trailer (Ps),
- Separate treatment of tractor units and semi-trailers under conditions of their coordinated and synchronized operation.

In the process of organization, the simplest approach is to treat the observed road train as a single operational unit (first case).

The organization becomes more complex when there are different numbers of tractor units and semi-trailers, with independent organization of both groups while achieving different operational and technical performance indicators (second case).

However, in some situations, even with separate treatment of tractor units and semi-trailers, it is necessary to consider them as elements of a single process (third case). In this case, their use and operation must be coordinated and time-aligned. A condition for this is balancing their numbers within a shared transport task.

Coordination of tractor units and semi-trailers

The synchronized operation of tractor units and semi-trailers in a continuous system can be disrupted by an increase in the driving time of tractor units and/or an increase in the duration of loading/unloading activities. In such situations, the equality between the driving interval (I) and the operating rhythm at loading/unloading points (R_u , R_i , and R_{ui}) is disturbed.

The causes of these disruptions can be identified through an analysis of performance indicators of both vehicles and loading/unloading locations. The criteria for optimizing the solution may vary, for example in terms of time losses and costs.