A New Operating Model for Single Wagonload Transport: From Train Formation to Integrated Customer Service

Miroslav Buc[1], Zdenka Bulková[2], Jozef Gašparík[2], Peter Ihnát[1]

[1]Železničná spoločnosť Cargo Slovakia, Inc., Tomášikova 28B, 821 01 Bratislava
[2]Department of Railway Transport, Faculty of Operation and Economics of Transport and Communications, University of Žilina, Žilina, 010 26, Slovakia

Abstract Single wagonload transport is one of the most complex production systems in rail freight transport. Its technological complexity results from the combination of local service, marshalling, shunting, long-distance haulage and subsequent wagon distribution to final customers. The aim of this paper is to propose a technological framework for the revitalisation of single wagonload transport in Slovakia, focusing on three key areas: time-organised train formation based on the overnight production cycle, the definition of a core network of train-formation and service nodes, and the separate organisation of the first and last mile. The paper builds on available data on the development of single wagonload transport in Slovakia, the European Union study on Single Wagonload Traffic and the technological principles of train formation. The result is an operating model combining the concentration of train formation in decisive nodes, regular overnight relations, regional collection and distribution links, digital information about wagon consignments and selective support for service points. The proposed model may serve as a professional basis for further discussion on maintaining and modernising single wagonload transport as part of sustainable rail freight transport.

Keywords single wagonload transport, train formation, overnight production cycle, marshalling yard, first mile, last mile, rail freight transport

JEL L92, R41, R48

1. Introduction

Single wagonload transport belongs to the traditional, yet also most demanding, products of rail freight transport. Its importance lies in the fact that it allows customers who do not have sufficient freight volumes to form a block train to be connected to the railway network. As a result, rail is not limited to large industrial and terminal flows but can also serve dispersed regional and industrial consignments [1].

In European terminology, this segment is referred to as Single Wagonload Traffic (SWL). The European Commission defines it as rail freight flows smaller than a full train, i.e. transport operations that are not carried out as a block train with the same train composition from origin to destination. According to the European Commission study, SWL represented a significant share of rail freight transport in the analysed countries, with an estimated volume of approximately 75 billion tonne-kilometres in 13 analysed countries and 80 to 85 billion tonne-kilometres in the EU and Switzerland [1].

Despite this significance, the single wagonload system has been under long-term pressure. The reason is its high technological and economic complexity. Compared with block trains, it requires considerably more shunting and train-formation operations, multiple handling of wagons, coordination between local and long-distance transport, more complex documentation and higher infrastructure requirements. In its business plans, Železničná spoločnosť Cargo Slovakia, a.s. (ZSSK CARGO) states that SWL is the most technologically and economically demanding transport system and that it ties up substantial technical and personnel capacities [2].

The significance of SWL cannot be assessed only through the business profitability of the operator. The European Commission regards SWL as an important part of rail freight transport, while also pointing to its structural problems: high costs of marshalling, shunting, distribution trains and the first/last mile. A Slovak study by the Ministry of Transport of the Slovak Republic further states that the current state of SWL transport, including the regulatory environment, is not sustainable in the long term in Slovakia and that the segment generates a negative financial result [1], [8], [9].

Discussion on the future of SWL therefore often focuses on public support. Such support is undoubtedly important, but it is not sufficient by itself. If support were provided without changing the technology, it would only extend the life of a costly system without substantially improving its quality and efficiency [8], [9], [12]. It is therefore necessary to search simultaneously for a technological model that reduces unnecessary handling interventions, accelerates wagon transfer through nodes, increases service predictability and better connects local service with long-distance haulage.

The aim of this paper is to propose a technological framework for the revitalisation of SWL in Slovakia. The focus is not on the financial support mechanism, but on the operating organisation of the system. The key elements are:

- time-discrete train formation based on the principle of the overnight production cycle;
- a core network of decisive train-formation and routing nodes;
- separately organized first and last mile;
- reduction in the number of wagon reclassifications;
- digitalization of consignment and wagon information;
- measurable service-quality indicators.

2. Technological Nature of Single Wagonload Transport

A single wagonload consignment is not merely a "small train". It is an independent production system in which individual wagons or smaller wagon groups are gradually collected, sorted and assigned to relations according to their destination. From a technological point of view, it is a chain that may include several links: siding or loading point - local collection - regional node - train-formation station - line-haul relation - destination sorting - local delivery - consignee [4], [19].

Each link in this chain creates costs, time dependencies and a potential risk of delay. If local collection is delayed, the wagon will not be transferred to the long-distance relation. If the line-haul relation is delayed, the wagon may miss the morning sorting or delivery to the customer. If connections between trains are not sufficiently stable, the entire system loses predictability [4], [19], [20].

The fundamental difference between a block train and SWL is therefore the number of technological handling operations performed on the wagon. In a block train, the objective is to maintain the train set in a stable composition. In SWL, the objective is to integrate individual wagon flows into efficient train relations. Train formation is therefore the core of the whole system [4], [20].

The operating principles of train formation emphasise that moving each wagon separately would be inefficient. Wagons are therefore organised into train flows, and the train-formation plan determines the train-formation stations in which wagons are reclassified and collected and prescribes their routing [4], [7].

Under current conditions, however, optimising wagon routing alone is not sufficient. It is equally important to align train formation with customer time requirements, railway network capacity and the availability of local service [4], [19]. This is why the principle of the overnight production cycle is relevant for SWL revitalisation.

The current network of train-formation stations on the infrastructure of Železnice Slovenskej republiky (ŽSR) forms a two-level operating structure: basic marshalling yards as the main nodes of long-distance train formation and other train-formation stations as regional points of collection, distribution and local service. An overview of all train-formation stations and their classification is given in Table 1 [7].

From the point of view of freight transport technology, the current situation is characterised by the concentration of decisive long-distance train formation in a limited number of basic marshalling yards. Other train-formation stations primarily perform regional, routing or service functions in relation to their catchment areas, local loads and links to through relation trains. This model corresponds to the trend of concentrating train-formation work in a smaller number of important nodes, while the efficiency of the system depends on the quality of links between basic marshalling yards, other train-formation stations and intermediate stations served by local service trains [7].

DOI: 10.26552/tac.C.2026.1.3

Table 1. Train-Formation Stations of ŽSR [7].

Group	Number	Stations
Basic marshalling yards	6	Bratislava východ; Čierna nad Tisou; Košice; Štúrovo; Zvolen nákladná stanica; Žilina-Teplička
Other train-formation stations	27	Banská Bystrica; Bratislava ÚNS; Devínska Nová Ves; Galanta; Haniska pri Košiciach; Horná Štubňa; Komárno; Kúty; Lenartovce; Leopoldov; Levice; Lisková; Lučenec; Lužianky; Nováky; Nové Zámky; Plešivec; Podbrezová; Prievidza; Prešov; Spišská Nová Ves; Strážske; Trebišov; Trenčianska Teplá; Trnava; Trnovec nad Váhom; Zohor
Total train-formation stations	33	basic marshalling yards + other train-formation stations

From the perspective of single wagonload transport, it is important that relation trains are defined in the Train-Formation Plan as trains intended for the transport of relation loads, i.e. single wagon consignments, including empty wagons intended for loading. Through relation trains provide the transport of long-distance loads between train-formation stations, whereas local service trains provide the distribution of local loads to sidings, public loading and unloading tracks and intermediate stations. This system represents the capacity and technological backbone for single wagonload transport on the ŽSR network [7]. For further stabilisation of the SWL system, reliable time, capacity and technological links between these levels are essential, particularly in the form of connections between local service trains, through relation trains and basic marshalling yards.

It should be emphasised that ZSSK CARGO uses the technological time of wagon collection to achieve the loading norm, both in terms of train weight and train length. This makes it difficult to determine the delivery time of a wagon consignment with sufficient accuracy [2].

Performance and economic data confirm that the current SWL system is significantly smaller than in the past. In a broader operating sense, the volume of SWL decreased from 17.5 million tonnes in 2005 to approximately 6.3 million tonnes in 2021, while its share in the transport structure decreased from 36% to 13%. Within the definition of SWL support according to the ZSSK CARGO 2026 methodology, the volume decreased from 3.8 million tonnes in 2021 to 2.5 million tonnes in 2025 [3]. At the same time, the overall rail freight market measured in gross tonne-kilometres is declining, and the share of ZSSK CARGO in this market is decreasing. These data support the conclusion that SWL on the ŽSR network is no longer only a technological issue, but also a strategic question of maintaining rail service for dispersed industrial flows.

3. Overnight Production Cycle as a Technological Basis for SWL Organization

The overnight production cycle, often referred to in Central European operational practice as the “night jump”, is a way of organising wagon consignments in which the decisive long-distance haulage takes place at night. Its logic is based on a simple operational and commercial assumption: customers need to load and unload during the day, while rail can effectively use night-time capacity windows for the long-distance movement of wagons [4], [19], [21].

The basic overnight production cycle can be described as follows:

1. D0 - daytime wagon collection: wagons are loaded and collected during the day at local service points, such as sidings, loading points and public loading and unloading tracks.
2. D0 - afternoon and evening collection: wagons are moved to regional or main train-formation nodes.
3. D0/D1 - overnight main haulage: collected wagons are moved between main train-formation nodes in regular overnight relations operated according to a fixed time regime.
4. D1 - morning sorting: wagons are sorted in the destination area into directions.
5. D1 - daytime distribution: wagons are delivered by local service trains to consignee sidings or loading points.

This principle transforms train formation from a continuous and not always predictable system into a time-organised network. The customer can thus receive clearer information about the latest time at which the wagon must be ready for dispatch and when delivery can be expected. The railway undertaking and the infrastructure manager can better plan capacity windows, shunting locomotives, classification tracks and staff [19].

However, the overnight production cycle is not merely an issue of timetable. It is a complete production regime. It requires:

- fixed cut-off times for wagon submission and collection;
- stable evening and night departures between nodes, i.e. a fixed timetable for freight transport;
- sufficient capacity of train-formation stations;
- reliable morning sorting;
- connecting local and service trains;
- an information system for tracking wagon passage.

If any of these elements fail, the benefit of the overnight production cycle is lost. Therefore, this principle must be designed as an integrated operating model, not merely as a selection of night train paths in the timetable [19], [21].

Table 2. Simplified Time Model of the Overnight Production Cycle [4], [19].

Phase	Time Period	Main Activity	Key Indicator
Daytime collection	D0, 8:00-16:00	Loading and preparation of wagons	readiness of wagon for collection
Evening collection	D0, 16:00-21:00	Movement to a regional or main node	compliance with wagon transfer time
Evening sorting	D0, 18:00-23:00	Sorting and formation of overnight trains	wagon dwell time in node
Overnight haulage	D0/D1, 22:00-5:00	Long-distance movement between nodes	compliance with night-time window
Morning sorting	D1, 4:00-7:00	Reclassification in the destination area	readiness for distribution
Daytime distribution	D1, 7:00-14:00	Delivery of wagons to consignee	delivery within guaranteed window

4. Core Train-Formation Network

For the overnight production cycle to function, it must be based on a clearly defined network of nodes. Not every station can perform the same function. A technologically efficient SWL system requires a multi-level structure [4], [7]:

1. main train-formation and marshalling nodes;
2. regional routing nodes;
3. satellite service points;
4. sidings and public loading points.

Main nodes should provide long-distance routes and overnight relation trains. They should have sufficient capacity of track groups, technical equipment, staff and digital support [19], [21]. Their role is not to serve every customer directly, but to create the backbone of the network.

Regional nodes should collect wagons from their catchment areas and distribute wagons arriving from the main network. They do not need to have the full function of a large marshalling yard, but they must be capable of efficiently organising service and local trains [4], [7].

Satellite points and siding form the capillary part of the system. Their existence determines whether rail can also reach small and medium-sized customers. If these points disappear, rail may remain strong in block trains, but it loses regional accessibility.

Historical development in Slovakia shows that the network of train-formation stations has been gradually rationalised. This trend is not incorrect, because concentrating train formation in more powerful nodes can reduce costs and increase quality. The problem arises when concentration is not accompanied by functional regional service. In that case the number of nodes decreases, but the accessibility of the service for customers also deteriorates [7].

The objective should therefore not be a mechanical restoration of all historical train-formation points. It is necessary to create a core network that combines concentration with accessibility.

Table 3. Functions of Nodes in the Proposed Core SWL Network [4], [7].

Network Level	Main Function	Typical Activities	Risk in Case of Absence
Main train-formation node	Long-distance routing and overnight haulage	marshaling, formation of relation trains, gateway links	loss of network coordination
Regional node	Collection and distribution of wagons	linking the catchment area, formation of wagon groups	extension of first/last mile
Satellite service point	Local service of the region	loading, unloading, local service trains	customers shifting to road transport
Siding/loading point	Direct customer interface	wagon placement and removal	loss of rail accessibility

5. First and Last Mile as a Critical Link

In discussions about rail freight transport, attention is often focused on the long-distance train run. In SWL, however, the decisive link is often the first and last mile. This is the phase in which the wagon enters the network from the customer and leaves the network back to the customer [1], [4].

First-mile and last-mile service is demanding because it:

- works with small volumes;
- requires shunting locomotives and staff;
- is spatially dispersed;
- often depends on a specific customer or siding;
- has lower productivity than line-haul operation;
- is sensitive to irregular orders.

If the first and last mile are not addressed separately, the SWL system cannot function. Even the best organised overnight network loses its significance if wagons do not reach the node from the siding in time or are not delivered from the node to the consignee [1], [4].

ZSSK CARGO states that SWL ties up high technical and personnel capacities and has a longer wagon cycle than block trains. It follows that optimisation must be focused precisely on those parts of the chain where capacities are tied up for the longest time and with the lowest productivity [2], [3].

Separate organisation of the first and last mile may take several forms:

- regional service contracts;
- a short-line or short-liner model;
- sharing of shunting capacities;
- service only in selected time windows;
- support for strategic sidings;
- linking SWL with regional terminals [6].

For Slovakia, a combined model is particularly appropriate. Some service points have strategic significance and should be included in the core network. Others may be served only when a minimum volume is reached or based on an individual calculation. Another group may be suitable for intermodal transformation [6].

6. Reducing the Number of Wagon Reclassifications

One of the most important technological indicators of SWL quality is the number of wagon reclassifications. Each reclassification means time, costs, risk of delay, the need for track capacity and shunting work [20]. The objective of a modern SWL model should therefore be to minimise the number of handling contacts with the wagon.

In simplified terms, three models can be distinguished:

- a traditional multi-stage model, in which a wagon passes through several routing and marshalling stations;
- a concentrated network model, in which wagons converge into main nodes and are subsequently routed by overnight relations;
- a hybrid model, in which strategic wagon flows remain in SWL and part of low-volume flows is transformed into intermodal transport.

For Slovak conditions, the second and third models are particularly suitable. The objective should be that most wagons in the core network pass through no more than one main train-formation node between the origin and destination regions [4], [20]. Ideally, the number of major marshaling interventions should be minimized to:

- regional concentration;

- main route;
- destination distribution.

If a wagon passes through too many nodes, the system loses competitiveness against road transport [1], [14], [20].

Table 4. Comparison of Technological SWL Models [1], [4], [20].

Model	Number of Reclassifications	Advantage	Disadvantage
Traditional multi-stage model	high	wide network accessibility	long times and high costs
Concentrated overnight model	medium	better predictability and higher productivity	higher dependence on main nodes
Hybrid SWL + intermodal model	selective	preservation of strategic flows and transformation of weak relations	higher requirements for decision-making and data

7. Digitalization as a Condition for Modern SWL

Technological revitalisation of SWL is not possible without digitalisation. Customers today expect simple service ordering, information on consignment position, estimated time of arrival and timely notification of deviations. If they do not receive this information, road transport or an intermodal operator is often more attractive [10], [18], [22].

Digitalisation in the SWL system should include:
- electronic consignment ordering;
- digital wagon status;
- wagon location tracking;
- information on connections;
- ETA prediction;
- electronic train documentation;
- connection to TAF TSI;
- service quality evaluation [10], [18].

In the future, Digital Automatic Coupling (DAC) may also play an important role. Its benefit for SWL may be greater than for block trains, because SWL is precisely the segment that involves frequent coupling, uncoupling and wagon sorting [10], [22]. DAC, however, cannot be regarded as a short-term solution. It is a strategic technology for which the system must gradually prepare [22].

In the short term, basic digital functions are more important: reliable data on wagons, consignments, arrivals, departures and connections. Without these data, the overnight production cycle cannot be managed effectively, and the quality of the core network cannot be evaluated [10], [18], [22].

8. Proposal of a Technological Model for Slovakia

Technological modernisation of SWL must be understood as a combination of organisational and digital measures. In European documents, DAC is presented as a tool for the digitalisation and automation of rail freight transport that can support higher capacity and productivity [10], [22]. In SWL conditions, its importance is specific because this segment works with frequent wagon reclassification. Based on the previous sections, a framework technological model for revitalising SWL in Slovakia can be proposed. It should consist of six elements.

8.1. Definition of the Core Network

First, it is necessary to determine which nodes, relations, sidings and commodity groups should be part of the core SWL network. Decisions should be based on transport volume, strategic importance, availability of alternatives and social benefits [7], [8], [17].

8.2. Introduction of Regular Overnight Relations

Stable overnight relation trains with guaranteed time windows should be operated between the main nodes. These fixed-timetable relations should form the backbone of the system [19], [21].

8.3. Linking Regional Service with the Overnight Cycle

Local and service trains must be timed to connect to evening departures and morning arrivals of relation trains. Without this link, the overnight production cycle loses its significance [4], [19].

8.4. Separate Organization of First and Last Mile

The service of siding and loading points should be planned separately. Strategic points should be included in the supported network, while others should be addressed according to volume or through an alternative intermodal solution [6].

8.5. Digitalization of Information

Each wagon in the core SWL system should have a digital status: relation, planned train, connection, ETA, technical restrictions and documentation status [10], [18].

8.6. Quality Measurement

The system must be evaluated regularly. Without measurement, it is not possible to decide which parts of the network are efficient and which should be transformed [17].

Table 5. Key Indicators of Technological SWL Revitalization [17], [18].

Area	Indicator
Time	average time from wagon-consignment submission to delivery
Train formation	number of reclassifications per wagon
Nodes	average wagon dwell time in the train-formation station
Quality	share of wagons delivered within the guaranteed window
Capacity	utilization of routing and departure tracks of decisive train-formation stations
First/last mile	number of served loading and unloading points, including public loading/unloading tracks, sidings and loading points
Digitalization	share of consignments with available ETA
Efficiency	cost per wagon or wagon-kilometer
Externalities	estimated number of avoided truck journeys

9. Discussion

The proposed technological model does not assume a return to the historical extent of train formation. Such an approach would not be realistic or economically justifiable. The aim is to create a smaller, but more stable and higher-quality network [7], [12], [13]. This network would be capable of serving strategic wagon flows, while not maintaining inefficient relations without sufficient significance.

At the same time, it must be emphasised that technology alone is not sufficient. Without an economic support framework, especially for first/last-mile service, the system will remain under pressure. Public support should, however, be linked to technological reform. The state should not support an inefficient status quo, but a modernised service with clearly defined parameters [8], [9], [12].

Another issue is the relationship with intermodal transport. Intermodal transport should not be understood as a competitor to SWL, but as a complementary transformation layer. Some flows that are currently, or historically were, wagonload consignments may in future be more efficiently handled using containers, swap bodies or other units. Conversely, for specific industrial commodities, direct wagon placement will remain irreplaceable [1], [6].

The greatest risk is a passive scenario. If neither technologically modernised SWL nor an intermodal alternative is supported, dispersed flows will shift to road transport. This may reduce the problem for the rail freight operator, but it increases the burden on public infrastructure, emissions, safety and regional accessibility [14], [17].

Foreign practice shows that maintaining SWL requires a combination of support and reform. Austria supports selected forms of rail freight transport through the SGV-Plus programme, while Switzerland approaches SWL as an ordered basic network with multi-annual financing. For Slovakia, this implies that any support for SWL must be stable, transparent and linked to technological modernisation, rather than merely compensating losses [12], [13].

10. Conclusions

Single wagonload transport cannot be revitalised by financial support alone. Above all, it requires a new technological and organisational model. Its core should be time-organised train formation based on the overnight production cycle, a stable network of decisive nodes, separately organised first and last mile, and digitalisation of wagon and consignment information [4], [10], [19], [22].

Slovakia still can maintain the core of the SWL system, but only if it moves from passively maintaining the existing situation to active modernisation. This means less randomness, more regularity, fewer unnecessary reclassifications, better customer information and a clear distinction between strategic and transformable flows [3], [6].

The proposed model does not mean preserving all historical wagonload relations. It means preserving those that have technological, industrial and social justification. Other flows should be assessed in terms of their potential transition to intermodal transport.

The future of SWL therefore depends not only on whether the state is willing to support the system. It also depends on whether the rail sector can offer a modern, predictable and technologically efficient product. The overnight production cycle, the core network and high-quality first and last mile can form the basis of such a change [1], [4], [19].

ACKNOWLEDGEMENTS

The paper is supported by the VEGA Agency by Project 1/0485/24 "Increasing the efficiency and sustainability of rail and water transport in the context of environmental impacts", solved at the Faculty of Operation and Economics of Transport and Communications, University of Žilina.

REFERENCES

[1] European Commission, Study on Single Wagonload Traffic in Europe - Challenges, Prospects and Policy Options. Final Report, Publications Office of the European Union, Luxembourg, 2015.

[2] ZSSK CARGO, Obchodné zámery ZSSK CARGO na rok 2022, Železničná spoločnosť Cargo Slovakia, a.s., Bratislava, 2022.

[3] ZSSK CARGO, Obchodné zámery ZSSK CARGO na rok 2026, Železničná spoločnosť Cargo Slovakia, a.s., Bratislava, 2026.

[4] J. Gašparík et al., Vlakotvorba a miestne dopravné procesy, 1st ed., Univerzita Pardubice, Czech Republic, 2011.

[5] J. Gašparík, J. Kolář, Železniční doprava: technologie, řízení, grafikony a dalších 100 zajímavostí, 1st ed., Grada Publishing, Czech Republic, 2017.

[6] Ministerstvo dopravy Slovenskej republiky, Koncepcia rozvoja intermodálnej dopravy Slovenskej republiky do roku 2030, Ministerstvo dopravy Slovenskej republiky, Slovakia, 2022.

[7] Železnice Slovenskej republiky, ND Plán vlakotvorby. Platí od 14. decembra 2025, ŽSR, Slovakia, 2025.

[8] Ministerstvo dopravy Slovenskej republiky, Aktualizácia kalkulácie oprávnených nákladov pre uplatnenie štátnej pomoci pre JVZ na rok 2023, Ministerstvo dopravy Slovenskej republiky, Slovakia, 2023.

[9] Ministerstvo dopravy Slovenskej republiky, Schéma štátnej pomoci na podporu železničných dopravcov pri nákladnej preprave jednotlivých vozňových zásielok, Ministerstvo dopravy Slovenskej republiky, Slovakia, 2026.

[10] Europe's Rail Joint Undertaking, Digital Automatic Coupling, Europe's Rail Joint Undertaking, Belgium, 2021.

[11] SCI Verkehr, Single-wagon Load Transport in Europe: Economic Significance and Funding Perspectives, SCI Verkehr GmbH, Germany, 2026.

[12] Schieneninfrastruktur-Dienstleistungsgesellschaft mbH, Förderungsprogramm SGV-Plus 2023-2027, SCHIG, Austria, 2023.

[13] Railmarket.com, SBB Cargo receives state subsidy for single wagonload freight until 2029, 2025.

[14] Interreg Central Europe, Work Paper: Single Wagon Load Transport, 2024.

[15] Deutsche Bahn, DB Cargo Transformation. Interim Group Management Report 2025, Deutsche Bahn, Germany, 2025.

[16] European Commission, Proposal for a Regulation of the European Parliament and of the Council on the Use of Railway Infrastructure Capacity in the Single European Railway Area, COM(2023) 443, European Commission, Belgium, 2023.

[17] European Parliamentary Research Service, CountEmissionsEU: Measuring Emissions from Transport Services, European Parliament, Belgium, 2023.

[18] UNIFE, Digital and Intelligent Rail Freight in Europe, UNIFE, Belgium, 2021.

[19] J. Pachl, Railway Operation and Control, 3rd ed., VTD Rail Publishing, USA, 2014.

[20] N. Boysen, M. Fliedner, F. Jaehn and E. Pesch, "Shunting yard operations: Theoretical aspects and applications", European Journal of Operational Research, vol. 220, no. 1, pp. 1-14, 2012. DOI: 10.1016/j.ejor.2012.01.043.

[21] International Union of Railways, UIC Code 406: Capacity, 2nd ed., UIC, France, 2013.

[22] Federal Ministry for Digital and Transport, Digital Automatic Coupling: Final Report / Migration Concept, BMDV, Germany, 2024.