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# MULTI-VARIANT CONFIGURATIONS OF SUPPLY CHAINS IN THE CONTEXT OF SYNCHROMODAL TRANSPORT

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**ABSTRACT. Background:** Transport needs are specific expectations of business organizations and depend on customers' preferences, availability of supra- and infrastructure and ecological awareness. This study aims at outlining global efforts towards sustainable development by utilizing transport means with optimized solutions and specific advantages of each transport mode. Novel concepts within multi-variant transport, such as co-modal or synchromodal transport, make up a basis for creating a higher standard of process organization, characterized by individual customized solutions.
**Material and methods**: Have been described the features and main characteristics of modern concepts synchromodal transport and identifies differences in relation to the well-known multimodal system. The paper presents a statistical analysis of the share of various modes of transport in intermodal transport in the last ten years. Conducted the examination of the significance of quality features of transport services on a sample of 613 companies chosen deliberately. The collected data were analyzed using two marking scales indicated determinants of composite supply chain.
**Results and conclusions**: The presented analysis of transport service qualities in the context of prospective synchromodal transport included participants of complex supply chains. The results show that they aim towards improvement of relations, co-operation and partnership in future process-related and strategic solutions.

**Key words:** supply chain, future logistics, synchromodal transport, commodity, multi-variability transport, transport service quality.

## INTRODUCTION

Modern entrepreneurs determine new strategies and trends aiming at successful business in the face of dynamically changing environment, global competition and clearly defined customer requirements. Major changes are also visible in the efficient organization of processes making use of various modes of transport and service quality.

There are new concepts in the logistics of cargo flows supported by many implementation programs on the domestic and international market. Effective use of transport vehicles, route optimization, grouping of destination points, reduction of redundant packages, skilful use of infrastructure and appropriate investment projects result in competitive advantage and attract customers. Fundamental object is outlining global efforts towards sustainable development by utilizing transport means with optimized solutions and specific advantages of each transport mode.


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## MULTIMODAL TRANSPORT AS AN ELEMENT OF INTEGRATED SUPPLY CHAIN STRATEGY

The main task of supply chain is to guarantee uninterrupted flow of cargoes, information and payments. These flows make up a system, defined as a set of logistic elements interconnected through transformation processes. The strategy of integrated management comprises all areas of a company, i.e. procurement, distribution, customer service, and it aims at the co-operation, integration and shortening of flow cycles and customer orientation [Rydzykowski, 2010]. These would not be possible without efficiently operating transport, coordinated on various levels: engineering, technology, organization. Various transport modes are used depending on transport needs, affected by: volume of supplies, type of cargo, location of markets, available infrastructure, carriage time, location of resources. The choice is also dependent on costs, safety and promptness of deliveries, recently the environmental impact. The creation of a responsible and sustainable transport policy based on the above aspects was supposed to change significantly the transport structure by increasing the share of other transport systems alternative to road, especially by intermodal configurations [Hajdul, 2009 and Nagurney, Liu, Wooley, 2007].

Conventional combinations of transport modes enable using optimal solutions and advantages of each mode, which should result in agile, unimpeded and flexible carriage in the bimodal, intermodal or multimodal system. Publications on the subject, particularly those in the English language, present a variety of concepts and definitions of multimodal transport. The characteristics of and relations between these concepts are presented in Table 1.

Table 1. Characteristics of multi-variant transport systems models and their interrelations
Tabela 1. Charakterystyka modeli systemowych transportu wielo-gałęziowego i związki między nimi

| Type of transport system | Multimodal transport | Intermodal transport | Bimodal transport |
|---|---|---|---|
| Main idea to the transport system | Carriage of cargoes by using at least two different modes of transport | Carriage of cargoes in one unit load using successive at least two modes of transport without handling the load | Transportation involving use two means of transport: road and rail, without reloading unit load |
| Features of the system | There is one contract of carriage obliged, in charge of the delivery of goods is a responsible contractor. Each carriers performs its task subordinated to the needs of transport processes across the supply chain which means reduction or loss of autonomy of the individual modes of transport [Szołtysek, 2009] | One contract of carriage obliged, only one contractor responsible for the course deliver. Each carrier realizes more or less autonomous tasks in the supply chain | Last section of road transport carries |
| Handling of cargo | Integrated unit loads, e.g. containers, swap bodies, semitrailers or motor vehicles, special containers;<br>*Cargo discretisation*, which means that only cargo unit is subject to manipulation | There is a need to load units with means that the cargoes are subject to handling and manipulation of constituent in full and container or means of transport. | Reloads the whole trailer from railway carriages to truck and vice versa |
| Sample projects implementations | GeCoTraM – Electronic system for container circulation management In multimodal transport for the European integration on the transport corridors cross Romania;<br>SUPERGREEN – Supporting EU's freight transport logistics action plan on green corridors issues | INTERMODA – Integrated solutions for intermodal transport between the UE and the CEECs;<br>PROMIT –Promote innovative intermodal freight transport | BiMo- Flexible transport chain: Integration of bi-modal transport into a closed loop transport services concept;<br>POSTRAIN - Bimodal innovative vehicle with two locomotive configuration |

Combined transport is a form of intermodal transport (included in the multimodal transport). Its characteristic feature is the fact that the major part of carriage is executed between terminals by rail,

inland or short-sea shipping, while feeder services are provided by road carriers over strictly specified distances.

Although there are favorable premises for intensive development of multimodal transport (location at major junctions of European transport corridors and growing transit traffic) [Krystek, 2005] Polish cargo transport market is dominated by road transport. Combined transport is perceived as a system that does not offer a real alternative to road transport, because technically it is not sufficiently flexible, too slow and unreliable in terms of delivery, and too expensive [Fagerholt, 2010 and Kazakov, 2010]. This opinion is supported by research on delivery promptness [Kwaśniowski, Nowakowski, Zając 2008]. Its results show that among many difficulties in timely delivering of cargo units by intermodal transport the most frequent delays are caused by the rail operator (as much as 65% of the examined sample, due to lack of proper rolling stock, delays due to previous delays, strikes, insufficient manning, errors in shipment sorting, equipment failures, railway works). Other causes include: delays during cargo preparation and carriage to terminals (11%), delays caused by terminal operators (3%), others (customs, automatic data identification, unidentified 21 %).

National efforts to implement sustainable transport policy are supported by a number of initiatives and the execution of programs (see Table 1, line: Sample projects implementations) aimed at the restoration of balance between the modes of transport, provision of open access to each transport market and reduction of harmful impact on the environment.

## THE CONTEXT OF CO-MODALITY WITHIN MULTI-VARIANT TRANSPORT

The processes of cargo flow concentration are accompanied by globally unprecedented in magnitude new logistic forms of organization and management, a prerequisite for time and cost effective control of information and financial glows, and for the satisfaction of demand for cargo quantities generated by globalization [Jain, Wadhwa, Deshmukh, 2009 and Tongzon, Chang, Lee, 2009]. Among the factors necessitating the changes in traditional approach are changing expectations of customers, including their environmental awareness, growing role of general cargo in trade and the location of production centers.

The co-modality of supplies, a relatively new term in transport logistics, first appeared in 2006. EU policy in this respect indicates the need to optimize the use of each mode of transport as a method for achieving a simple and efficient transport system by replacing competition with the concept of complementarity. Such approach gains importance in European transport and logistics as it is economically attractive in terms of flexibility, accessibility, promptness, multiplication of financial efforts for infrastructure, cost reduction and availability of information in real time.

With the objectives defined as above, it may turn out that in a given transport process only one mode of transport can be employed, and that is 'heavy' road transport, e.g. in the modular system. The very idea of co-modality does not assume that intermodal transport is necessary and justified. What it assumes is that to strive for the above mentioned objectives, the decision on one or more modes of transport should be considered. However, it is assumed that shifting a part of long distance road transports to other modes will be encouraged in the light of growing congestions on European road network, lengthening travelling time of vehicles and delivery delays [Archutowska, 2009].

It should be borne in mind, though, that each transport process, according to sustainable development and main guidelines of co-modality of supplies, will be evaluated in respect to eco-logistic solutions, meeting customer expectations and cost reduction. The latter factor still remains the most significant for a majority of companies.

### Creating a modern intelligent transport policy by synchromodal system

Innovative actions aimed at the effective organization of transport processes require that all participants of the supply chain maintain bilateral co-operation, based on mutual trust and partnership,

especially long-term relation of trust. The concept of synchromodal transport creates a multimodal transport policy at a higher level of process organization (see Figure 1), based on combinations of co-modal transport with proper scale of individualized solutions.

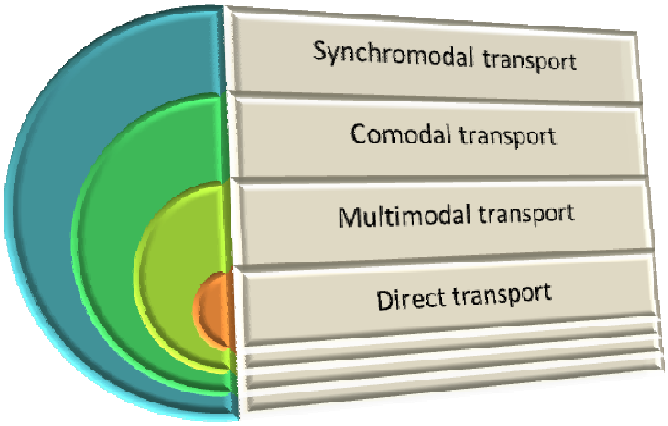


Fig. 1. The levels of process organization in transport multi-faceted
Rys. 1. Poziomy organizacji procesowej w transporcie wielogałęziowym

Synchromodal transport is an innovative, promising idea of flexible and sustainable utilization of transport resources based on the co-operation of carriers representing various transport modes, adjusted to customer requirements and current transport capacities [Fernandez, Cea, Soto, 2003 and Holmgren, 2012]. Unlike intermodal transport, where cargo is moved in a specific direction, i.e. from a point of shipment to its destination by an initially chosen transport vehicle, synchromodal transport assumes that at any moment one of several options of transport connections is chosen. This means that in real time the best available methods of transport are used.

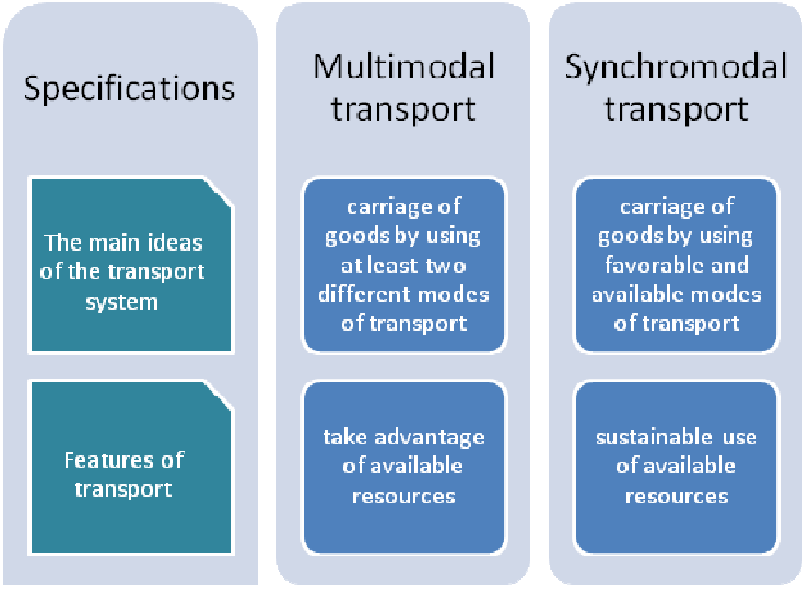


Fig. 2. Main assumptions synchromodal concept in combinations with multimodal transport
Rys. 2. Główne założenia koncepcji sychromodalnej w zestawieniu z transportem multimodalnym

An optimal decision is preceded by detailed recognition of customer preferences, analysis of multi-variant combinations of services and the estimation of possible results. Such approach demands from supply chain participants honest and up-to-date information exchange, for which a properly configured

computer platform cannot be overestimated. The key requirement for smooth and dynamic operation of the system is the creation of skeleton networks as a backup of main seaports, logistics centers, container terminals. The system needs a compatible network, efficient operators, appropriate allocation of transmission capacities, effective utilization of infrastructure and suprastructure, and the implementation of intelligent transport systems. General assumptions of innovate concepts and differences compared to the multimodal transport shows Figure 2.

Synchromodal transport furthermore implies making optimum use of the factor time: push instead of pull. Containers no longer remain at the deep-sea terminals in anticipation of action on the part of the recipient (pull), but are directly moved by barge or train to the inland terminals in the hinterland in a pro-active fashion (push). The realization of a synchromodal transport system is not that easy. The consolidation of volumes is essential in this respect. Only then frequent connections are possible between all the hubs using all three modalities: rail, inland shipping and road [Fransoo, 2011]. The result is an optimal sustainable and reliable transport system.

In terms of technology, innovative solutions are related to increased capacity of a road vehicle, e.g. by using double loads on the bottoms of trailers and semi-trailers, increasing the maximum vehicle length, or wider use of standard Euro-pallets for cargo unitizing. It is worth noting that of all EU countries there are only two that allow the movement of road trains longer than 18.75 meters: Finland (25.25 m) and Sweden (24.00 m). Regulations on allowable maximum mass of vehicles in road traffic also vary: from 38 tons in Austria, 40 tons in Poland, 50 tons in Holland, to 60 tons in Sweden. Therefore, the best instrument for promoting synchromodality in supply chains will be revised and harmonized transport regulations. Apart from the variety of vehicle parameters, other obstacles for the idea of synchromodality are coordination problems in individual transfer junctions, demurrages, insufficient infrastructure, lack of standardized data exchange, unequal engagement of co-operating parties. Pilot implementation of the innovate concept is currently realize between Rotterdam and Tilburg in the south of the Netherlands. This concept entails the optimal operational alignment of shippers and carriers in their choice of transportation modality and infrastructure. This operational alignment is characterized by 1) the ability to switch freely between modalities and logistics networks whenever desirable and 2) by being able to aggregate and bundle transport loads to enjoy the benefits of economies of scale.

**Quality services in a multi-faceted supply chain - case study**

Effective organization of transport processes becomes increasingly difficult due to minor role of rail, sea and inland waterway transport in cargo traffic compared to the market share of road transport (see Picture 3).

According to analyses of the Railway Transport Office (UTK) the fraction of intermodal transport in the first three months of 2011 showed a rising trend compared to the same period a year before. By the end of March the following results were recorded: carriage of 980,000 tons of commodities, overall transport work covered 418 million ton-kilometers, which compared to the previous year meant an increase of railway freight in combined carriage by, respectively, 18.2% and 19.3%. However, it is still a slight fraction in the transport market oscillating at 1.95% of the mass carried and 3.96% of performed carriage work.

Although in the short run frequent and prompt deliveries by road meet customer needs and contribute to the improvement of processes, the use of more vehicles in the available road infrastructure may lead to congestions and reduced average speed of deliveries, with consequent delays and reduced traffic safety. Inclusion amount of cargoes transport in 2010 year, with the context of the average distance traveled by the mode presented Figure 4. It is concluded that the dominant road transport (84.4% of transported cargoes) while performing traffic on the shortest average distance equal to 144 kilometers and the railroads that transported 11.8% of the average distance cargo transport recorded at 225 kilometers.

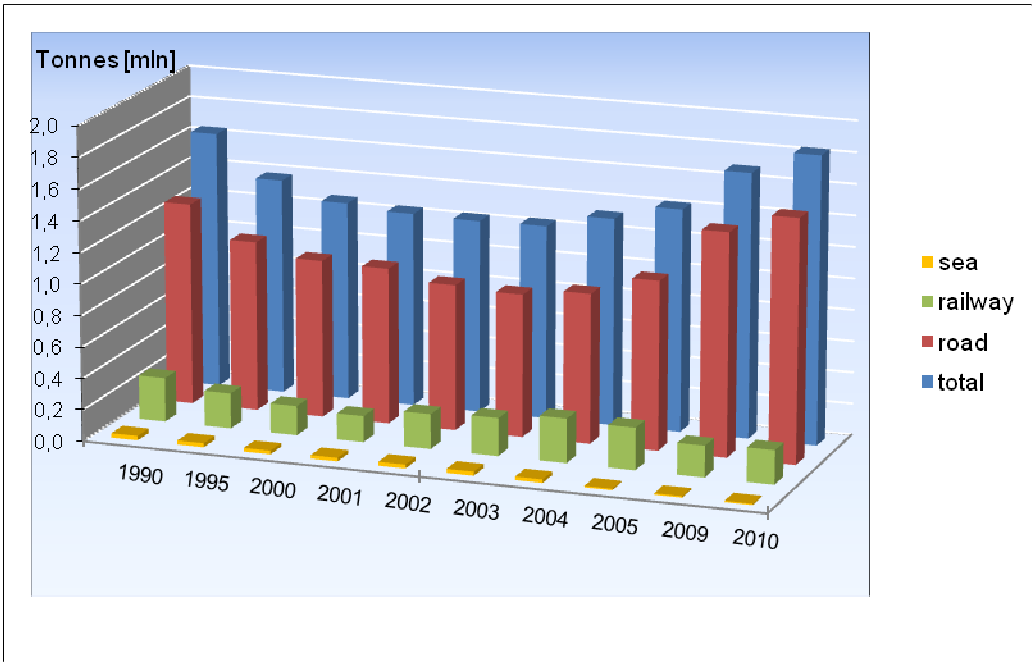


Fig. 3. The volume of freight transport based on mode of transport
Rys. 3. Wielkość przewozów towarowych z uwzględnieniem rodzaju transportu

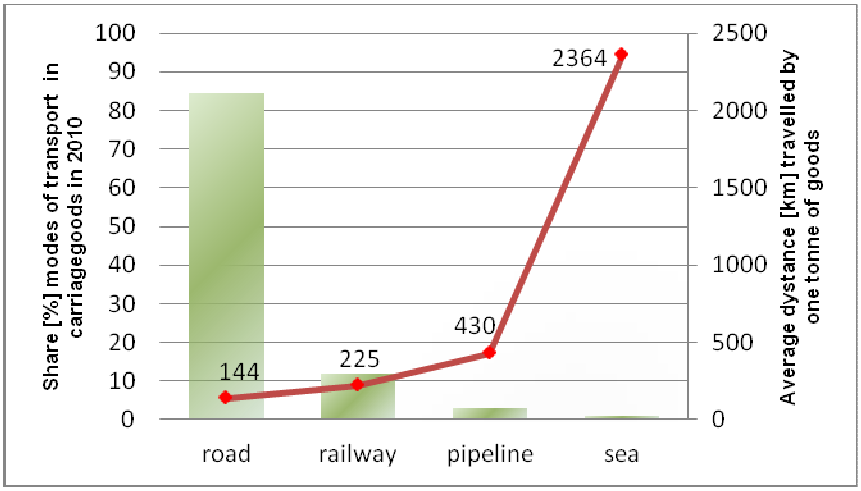


Fig. 4. Participations in various modes of freight transport in comparison with average distance a tone of cargo
Rys. 4. Udział poszczególnych gałęzi transport w przewozach towarowych w zestawieniu ze średnią odległością jednej tony ładunku

It should be noted here that the transport service quality depends on the satisfaction of customers from the service, but also their overall assessment they make by balancing positive and negative impressions related to the organization and all services it provides. Notably, among reasons for contacting a particular service provider may be the felt intensity of the customer's needs, their financial capacity and the flexibility of service offer of the provider [Łańcucki, 2010]. Taking into account the evaluation of customer satisfaction from services provided, we analyzed a number of features determining the suitability of a given mode or vehicle for fulfilling a transport need.

The examination of the significance of quality features of transport services in the complex supply chain in the context of innovative strategy of synchromodal transport included 613 samples. The companies were selected on purpose, i.e. those actively participating in organized cargo flows. Respondents showed a stable opinion, that is their long time presence on the market guaranteed

objective opinions. Results from companies operating less than seven years or those with financial liquidity defined as 'low' or 'close to zero' were omitted. Completely filled out questionnaires were delivered by 141 respondents. Transport processes taking place in multi-level supply chains were evaluated using two marking scales. One covered descriptive research based on bipolar interval scale, identifying essential determinants of transport services by the prioritizing of features indicated in the questionnaire. The other accounted for the significance of a feature in terms of dynamic relations between an attribute and attribute significance, comprising such determinants: readiness, continuity, credibility, safety, mobility, promptness, flexibility, reliability. These were analyzed in two areas: direct deliveries - one vehicle used, usually a road truck, and multimodal deliveries with various configurations of available means of transport (at least two different modes).

The level of participant supplies satisfaction is shown in Figure 5.

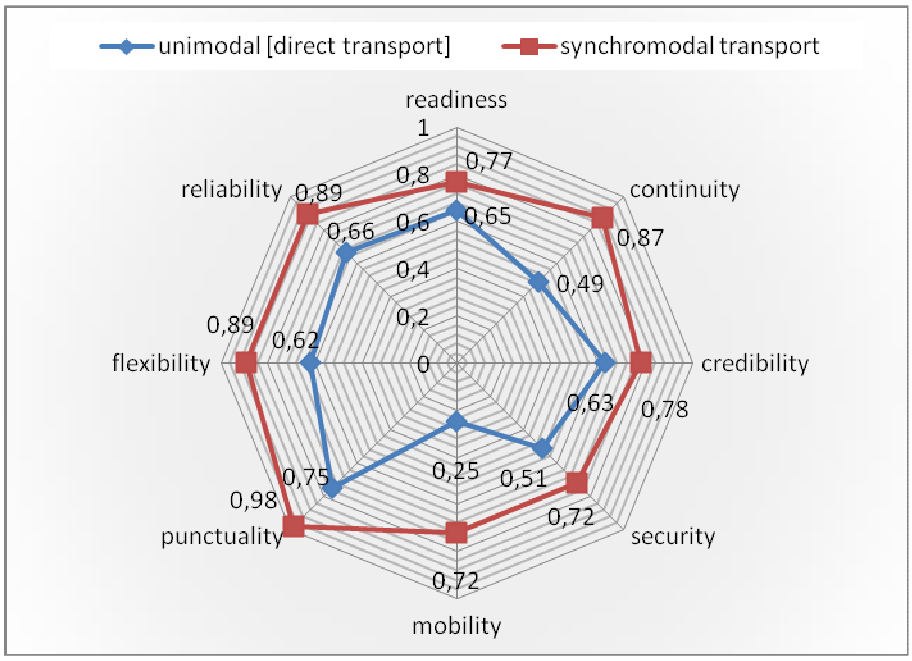


Fig. 5. Significance of quality features of transport services provided in direct and combined deliveries
Rys. 5. Ważność cech jakościowych realizowanych usług transportowych w dostawach bezpośrednich i złożonych

It will be noted that all examined quality features of services provided as direct deliveries or combined transport have attained a significance level higher than 50%. Interestingly, only 25% of respondents representing road transport participants indicated 'mobility' as an essential feature for customer satisfaction, although this mode of transport is most frequently used for door-to-door services. Multimodal transport requires from its participants more involvement, service integration and better arrangement of distribution structures - the significance level of the features ranged from 72% (safety and mobility) to 98% (promptness), which may indicate that each individual feature as well as all of them combined play a significant role in the complex transport process.

## CONCLUSIONS

Innovative concepts of transport process management leading to effective adjustment to market requirements point out directions in which modern companies should develop. Customized offers of integrated and comprehensive services based on mutual trust, co-operation and partnership will be determinants of effective and progressive logistics. The following conclusions can be formulated:

- coordination creates efficiency,
- data exchange is really crucial to raise logistics to a higher level,
- synchromodality is an essential pre-condition for optimally and sustainably organizing transport in the future,
- customer criteria in that respect are (in varying orders) reliability, efficiency, price, speed and, increasingly, sustainability,
- strategic collaboration alone will not suffice. To further streamline logistics in the future, the business community must also simply cooperate at the operational level.

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# WIELOWARIANTOWOŚĆ KONFIGURACJI ŁAŃCUCHÓW DOSTAW W KONTEKŚCIE KONCEPCJI TRANSPORTU SYNCHROMODAL-NEGO

**STRESZCZENIE**. **Wstęp:** Potrzeby transportowe są pożądanymi przez gospodarkę oczekiwaniami zależnymi od preferencji klientów, dostępności supra- i infrastruktury, świadomości ekologicznej. Celem opracowania jest wskazanie światowych dążeń do zrównoważonego rozwoju i wykorzystania środków transportu z uwzględnieniem optymalnych rozwiązań i zalet każdej z gałęzi. Nowatorskie koncepcje w obszarze transportu wielowariantowego, jak transport komodalny, czy synchromodalny stanowią fundamenty kreowania wyższego poziomu organizacji procesowej z uwzględnieniem rozwiązań zindywidualizowanych.
**Metody:** Opisano cechy i główne założenia nowoczesnej koncepcji transportu synchromodalnego oraz wskazano różnice w odniesieniu do znanego systemu multimodalnego. Przedstawiono analizę statystyczną w zakresie udziału poszczególnych gałęzi transportu w przewozach intermodalnych w ostatnich dziesięciu latach. Przeprowadzono badania ważności cech jakości świadczonych usług transportowych na próbie 613 przedsiębiorców dobranych celowo. Zebrane dane przeanalizowano w przekroju dwóch skal ocen uwzględniając wyróżnione determinanty dostaw wielogałęziowych.
**Wyniki i wnioski:** Przeprowadzona analiza cech jakości świadczonych usług transportowych w kontekście perspektywicznej koncepcji synchromodal transport obejmująca uczestników złożonych łańcuchów dostaw wskazuje na dążenia w kierunku doskonalenia relacji, wzajemnej współpracy i partnerstwa przyszłościowych rozwiązań procesowych i strategicznych.

**Słowa kluczowe:** łańcuch dostaw, logistyka przyszłości, transport synchromodalny, komodalność, transport wielogałęziowy, jakość usług transportowych.

# MEHRVARIANTEN-KONFIGURATION VON LIEFERKETTEN IM KONTEXT DES SYNCHROMODALEN TRANSPORTS

**ZUSAMMENFASSUNG. Einleitung:** Transportbedarf ist eine von der Wirtschaft sehr gefragte Erwartung, die von Kundenpräferenzen, ferner Zugriffsmöglichkeiten an die Supra- und Infrastruktur sowie vom ökologischen Bewußtsein abhängig ist. Das Ziel der Abhandlung ist es, auf die Welttrends zur nachhaltigen Entwicklung und Inanspruchnahme von Transportmitteln unter Berücksichtigung optimaler Lösungen und Vorteile jeder Transportart hinzuweisen. Innovative Konzepte im Bereich des Mehrvarianten-Transports wie ko- oder synchromodalen Transports bilden eine Basis für Ausgestaltung eines höheren Niveaus innerhalb der Prozeßorganisation unter Berücksichtigung der individualisierten Lösungen.
**Methoden:** Im vorliegenden Beitrag wurden Eigenschaften und Hauptgrundsätze des modernen synchromodalen Transport-Konzeptes beschrieben und Differenzen in Bezug auf das multimodalne Transportsystem geschildert. Dabei stellte man die statistische Analyse im Bereich der Beteiligung einzelner Transportzweige an den intermodalen Transporten innerhalb der letzten zehn Jahre dar. Ferner wurden Nachprüfungen der Gültigkeit von Qualitätsmerkmalen in Bezug auf die Transportdienstleistungen anhand einer Probe von 613 gezielt ausgewählten Unternehmen durchgeführt. Die ermittelten Daten wurden bei Inaspruchnahme und Vergleich von zwei Beurteilungsskalen unter Berücksichtigung der ausgesonderten Determinanten von Mehrzweig-Anlieferungen analysiert.
**Ergebnisse und Fazit:** Die durchgeführte Analyse der Qualitätsmerkmale von Transportdienstleistungen weist im Kontext des zukunftsträchtigen Konzeptes des synchromodalen Transports, welches Teilnehmer der komplexen Lieferketten umfaßt, auf die auf die Vervollkommnung von gegenseitigen Relationen sowie der Zusammenarbeit und Partnerschaft innerhalb von zukünftigen strategischen Prozesslösungen ausgerichteten Versuche hin.

**Codewörter:** Lieferkette, Zukunftslogistik, synchromodaler Transport, Komodalität, Mehrzweig-Transport, Qualität von Transportdienstleistungen.

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