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Logistics Coordination Based on Inventory Management and Transportation Planning by Third-Party Logistics (3PL)

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Abstract: Currently, there is still a strong trend in research and in the market connected with the role of 3PL (third-party logistics) companies and the trend of developing and creating coordination in logistics networks. The most important issue for the following paper is the examination of the 3PL enterprise, which is able to create the demand forecasts to gain the functions of logistics coordination in the fields of inventory management and transportation planning. This research paper focuses on showing the demand forecasting tool results for 29 chosen distribution networks (in this paper, the traditional forecasting methods were used based on time series exponential smoothing, ARIMA, machine learning and neural-network-based methods, created in the R programming environment). In the next steps, the forecasting results were compared in the conditions of transportation planning and inventory management (in the conditions of "future" dynamic ABC analysis). The forecasting function supports the inventory management and transportation planning activity of 3PL as a key element of logistics coordination in distribution networks. The proper way to transfer the results of forecasting to an ABC analysis and transportation planning concept is to create a cloud-based system supported by data from the WMS (warehouse management system), while providing the possibility of results visualization by using some BI (business intelligence) solutions or different tools to create managerial information dashboards. Currently, one of the most efficient models connected with logistics coordination is the centralized network with 3PL responsible for planning and executing logistics processes with the creation of additional value. As such, 3PL is able to create a similar forecast for different types of DN and with different aggregations (per SKU or per recipient). It could support coordination in DN from the point of view of inventory management and transportation planning.

Keywords: 3PL; distribution network; demand forecasting; inventory management; logistics service provider; R programming; transportation planning

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1. Introduction

In today's market, outsourcing could effectively reduce logistics costs, the extra services burden and delays in services [1]. A lot of enterprises are striving towards the issue of focusing only on their main activities and finding contractors to fulfill other processes. Logistics activities are one of the most frequently outsourced areas, but on the other hand (as is noted, among others, by [2]), logistics processes are critical for supply chain operations. There is a reason why 3PL (third-party logistics) entities are so important in today's manufacturing, distribution and retailing processes. In the following article, under the definition of 3PL, the enterprise that designs, manages and controls the supply chain of another company will be understood [3]. Furthermore, in the following paper, 3PL will be used interchangeably with the logistics service providers, LSPs, and logistics operator.

Contemporary 3PL enterprises increasingly try to affect the actions of other companies on the market and try to develop the proper structure of added value in logistics processes. As such, 3PL enterprises continuously improve their offering of services to gain a competitive advantage in the logistics-service-provider market [4]; it also includes the specialized services offered on the market. Further, 3PL entities try to react to current disruptive situations in the supply chain. For example, 3PL enterprises built their resilience for COVID-19 into five main areas: the creation of revenue streams, enhancing transportation flexibility, enforcing digitalization and data management, optimizing logistics infrastructure and optimizing personnel capacity [5].

Arm in arm with outsourcing, in the literature, there is also the conception of coordination, which provides a lot of benefits to whole supply chains and distribution networks (DN) and allows the logistics processes to be executed with proper efficiency and effectiveness. Coordination has been considered in the literature for a long time, but it is still associated with being a background for basic conceptions of today's trends, such as, for example, Industry 4.0 [6], and contemporary logistics solutions are aimed at sustainable business solutions and attempt to coordinate whole nodes in fulfilling customers' demands [7]. Coordination means the integration of all processes to ensure sharing of the information, managing relationships and technology management [6]. One of the most explored coordination models in supply chains is the coordination with the leader node [8]. Because of the critical meaning of logistics processes, coordination of the supply chain actions, as well as huge experience and knowledge of 3PL in the area of executing and improving logistics processes, the author wanted to develop the conception connected with logistics coordination in DN. The literature review allowed the general assumptions of the mentioned conception to be described, and for the empirical work, the author chose aspects connected with inventory management and transportation planning based on current 3PL experience and new, possible-to-gain, functions of demand forecasting (DF). The author decided to connect the contemporary conceptions of coordination, centralized demand forecasting and the influence of 3PL in today's market to the considerations about the possibility of transferring the function of coordination (in the area of logistics operation in a distribution network) to the logistics service provider. Nowadays, the usage of outsourcing in the field of logistics is usually aimed at providing environmental sustainability [9] and supporting other companies that are striving towards achieving the sustainable development goals [10]. In the author's opinion, expanding the operations of 3PL in DN will also provide benefits in the field of sustainability.

The research sample connected with checking the possibility of developing a DF tool, the results of which could be used as a basis for logistics coordination, was checked on the example of the chosen 29 DN. The conception of DF by 3PL was developed in the area connected with transportation planning, where the general conception and information dashboard were shown, and in the area of inventory management, where the author showed the proof of concept developed as pilot research for one of the international 3PL companies, which provides the possibility of usage, and it is concluded by using a modified version of ABC stock analysis. The following research paper answers the questions connected with the way of transforming the forecast's accuracy, achieved by 3PL, to support their inventory management and transportation planning activity and the question connected with the possibility of developing an automated solution for stock management in DN. The process of hypotheses verification will be supported by analyzing the following research questions:

RQ1: How can the results of a forecast's accuracy, achieved by 3PL, be transferred to measure the supporting of inventory management and transportation planning?

RQ2: Which elements should be fulfilled to state that 3PL is able to automate the process of stock management in the distribution network?

The answer for the first research question (RQ1) allows us to establish a measurement for checking the possibility of supporting the chosen logistics coordination elements through the DF tool. The result of the second question (RQ2) allows one to create the set of elements helpful during the automation of stock management processes. The main purpose of the article is to analyze the concept of logistics coordination, including inventory management and transportation planning, using a prepared demand forecasting tool.

The following research aims to fill the gap in the logistics coordination concept in the field of logistics coordination conception standardization and show the possibilities of developing the centralized forecasting in the 3PL company as the key element of the mentioned conception. The research is connected with gaining new, value-adding functions through logistics operators: demand forecasting and logistics coordination.

2. Theoretical Background

2.1. Logistics Coordination Concept

Coordination of activities, according to literature, may consist of: preventing conflicts in DN [11,12], organizing the activity of two or more groups in such a way that they work together and are aware of the activities of other entities [13] and integration and synchronization of activities related to decisions concerning demand forecasts, inventory management and their replenishment [14]. Coordination depends on network configuration [15]. This provides a basis for the claim that the appropriate configuration of the DN may significantly affect the level of coordination of activities related to the demand [3].

In the case of logistics outsourcing in the advanced version, one of the most important issues is providing information sharing and process coordination [16]. What is interesting is that the same authors rejected the hypothesis of supporting the basic version of outsourcing by information sharing, but on the other hand, coordination between logistics companies, for example, resource sharing, can positively affect the efficiency and sustainability of logistics operations in the whole network [17]. There are some models of coordination strictly connected with 3PL and coordination issues. Usually, they are striving for coordination in the production processes [1]. Sometimes, in the literature, there are considerations about the centralized system of demand disruption management. For example, [18] elaborated the model of demand management strategy, which contains suppliers and a few retailers. Coordination models are also described by game theory models [2] or taking into account only a few or one variable, such as costs [19]. However, one of the most prospective models concerned the centralized policy of supply chain or DN. This kind of solution usually provides lower retailing prices and higher logistics service quality [19]. Existing middleman nodes in DN are currently treated as a panacea for coordination [20]. These authors elaborated a mathematical model consisting of factors, such as relevant information and value creation. Similar models were also established in the case of reverse logistics [21] but are usually focused only on the logistics cost aspects [17].

The conception of supply chain coordination, which is important from the following article's perspective, is the conception elaborated in 2008 [22] and extended by these same authors in 2011 [23]. The mentioned researchers consider functional coordination (which includes separately: logistics, inventory management, forecasting, and product design) and the coordination connected with an interface in the supply chain, which is divided into coordination at the meeting point of supply and production, production, and inventory, production and distribution, distribution and inventory. These same authors also consider different issues connected with information sharing and technologies, which in their approach, are treated as one coordination mechanism. In modern approaches, in many cases, the blockchain is also considered a technology with high potential to improve the reliability of information flows in logistics networks [24]. In approaches connected with centralization and a leading node, the crucial issues are about developing proper coordination mechanisms. Coordination mechanisms are playing a very important role in gaining individual targets of whole nodes in DN [1]. Coordination in the logistics network, especially proper adjusting of coordination mechanisms, also has a strong influence on sustainability [25]. The mentioned mechanisms could also be used for handling the demand in networks [26]. Coordination of tasks related to demand management is one of the crucial challenges in achieving an efficient forecasting system in DN [11,27]. Coordination becomes particularly important in conditions of uncertain demand [27,28]. Key enablers of coordination according to some authors could be classified into three categories [29]: contractual, procedural and technological factors. Contract mechanism plays an important role in supply chain coordination. Revenue contract sharing is stated as one of the effective methods of coordination [19]. The importance of contract mechanism could be a success factor for developing coordination based on 3PL actions because currently, such a company bases their activity on contracts with partners. The coordination mechanism concept, which is more suitable for the topic of logistics coordination, in the author's opinion, is the conception (presented in [30,31]) that assumes the three main network coordination mechanisms: market, social and hierarchical. The developed logistics coordination concept is also connected with consideration about transportation, inventory management and demand, adding considerations about the possibility of taking the function of an entity that is creating a demand forecast and managing the inventory in the DN through a logistics operator [3] and information technologies, which, currently, need to appear for whole actions in DN. The general concept of logistics coordination is shown in Figure 1.

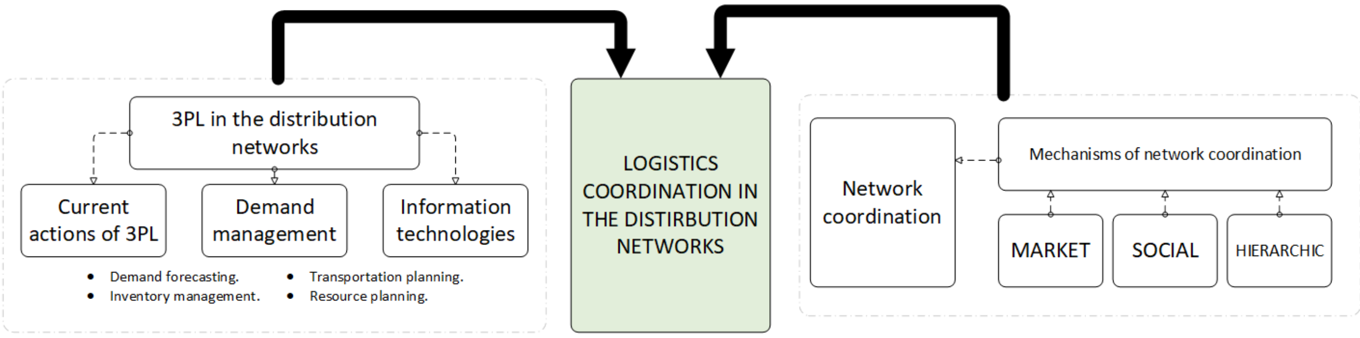

Figure 1. Concept of logistics coordination.

The basis of the logistics coordination conception is 3PL operational actions in DN, which are supported by the demand management and forecasting activity of such companies. The supply chain becomes a demand chain [32], which means the demand side of the supply chain is the most important thing in it. One of the most common strategies to predict the future quantity of demand is the usage of forecasting methods. Forecasts are the critical input element for deciding the area of supply, production, supplies and warehousing [29,33], which is mentioned in the literature many times. Therefore, 3PL, is considered by taking the function of demand forecasting needs to have specific features [3]. Information technologies could also support the ability of 3PL in the conditions of coordination and should also be able to conduct the actions connected with resource planning in the DN connected with worker and infrastructure planning in DN. Two factors that are the most important from the research paper's point of view and that will be considered in the empirical research are inventory management and transportation planning.

2.2. Inventory Management and Transportation Planning by 3PL in the Case of Logistics Coordination

Inventory management is an area of logistics coordination, on the one hand, aiming to reduce unforeseen fluctuations in demand and ensure an appropriate level of customer service in DN, and on the other hand, an area that largely depends on the adopted strategies for planning and implementing demand plans [34]. Proper handling with inventory management also has a positive impact on supply chain sustainability [35] because the coordination in the case of inventory management allows (among others) for a reduction in the supply level in the whole network and to minimize the waste in stocks. An interesting fact is that while stocks are generally held to meet demand, in some situations, they are held to stimulate demand [36] through, e.g., active influence in the sphere of customers. In the literature, this effect is called the psychic stock effect. According to the author, a logistics operator could both manage inventories for the purpose of their effective deployment in particular places in the supply chain and attempt to eliminate the bullwhip effect. These aspects could be positively influenced by the operator's experience in the implementation of logistics tasks and the ability to react quickly and adapt activities to the requirements of individual cells. The contemporary challenge of inventory management is handling demand fluctuations, stockouts and managing the individual SKUs (Stock Keeping Units), while also handling big data [37]. Management from the level of individual SKUs is problematic in terms of the amount of data and information that are associated with it. Inventory management based on big data can lead to advantages, such as [38]:

- Improving operational efficiency;
- Maximizing profits and sales;
- Increasing customer satisfaction rates;
- Reducing IT infrastructure costs by migrating to the cloud.

Logistics operators currently provide plenty of services related directly to inventory and stock management. They could also carry out inventory management activities for the entire network. Inventory management from the perspective of the entire network would enable its efficient coordination by means of planning and implementing assumptions related to the allocation of supplies and their effective use.

On the other hand, now, we are dealing more and more often with a one-day-delivery standard in transport operations [39]. As mentioned by some authors, through appropriate transport planning, 3PL could reduce flow times and reduce inventory levels [17] by increasing the speed of reaction and eliminating the need to maintain high-safety stocks. Transport operations, and in particular, the ability to carry them out efficiently and flexibly, play an important role in the coordination of the DN. In addition, many companies from the 3PL group provide transport services. Transportation is also one of the most crucial logistics operations for the environment. Wise coordination in the area of transportation could lead to providing an improvement in sustainability level [40]. There are so many of these enterprises that the problem becomes the choice of the right operator to provide transport services. Numerous mathematical models appear in the literature, which are used to assess and select the operator. An example could be the model (presented in [41]), which developed three main criteria for assessing the operator's ability to perform transport services efficiently. The first criterion is the possibility of developing sustainable cooperation, which mainly manifests itself in generating low transport costs, good financial conditions, correct reputation and showing similar values between enterprises. The second criterion is ensuring an appropriate level of service quality, which is mainly manifested in keeping the on-time delivery ratio at a high level, speed of response and reliability of deliveries. The last criterion is the ability to continuously improve, mainly related to technological sophistication, solid infrastructure and the ability to optimize operations. Undoubtedly, these criteria must be considered when choosing an operator that will be able to coordinate the company's activities in the DN.

Therefore, the proposed solution is based on a few concepts, which are summed up in Table 1.

Table 1. Leading conception elements.

Source	Influence of Conception Showed in the Paper
[32]	Rebuilding the structures of supply chains and accentuation of the demand side of logistics networks.
[3,42]	3PL enterprise ability to demand forecasting and demand management in centralized DN.
[8]	Proposed coordination model with leader node in DN.
[43]	3PL creates value in logistics networks.
[23]	Functional coordination with separate considerations about logistics, warehouse management, and production.
[30,31]	Market, social, and hierarchical network coordination mechanisms.
Proposed concept	3PL as a node in the DN which is able to create coordination actions from the logistics processes point of view.

3. Research Framework

In the following paper, the author shows the influence of the 3PL entity (which is able to create the forecasts in the DN) on the chosen elements of logistics coordination. Research focuses on the prepared research model (Figure 2). The research model is based on the assumption of a maturity model in the supply chain and could be applied to the distribution network, which possesses the technology infrastructure connected with data processing in WMS and cloud-based systems. It also applies to the maturity model in sustainability, which assumes, among other things, the usage of new technologies, the ability to analyze and conclude and implement a huge range of tools connected with network performance [44].

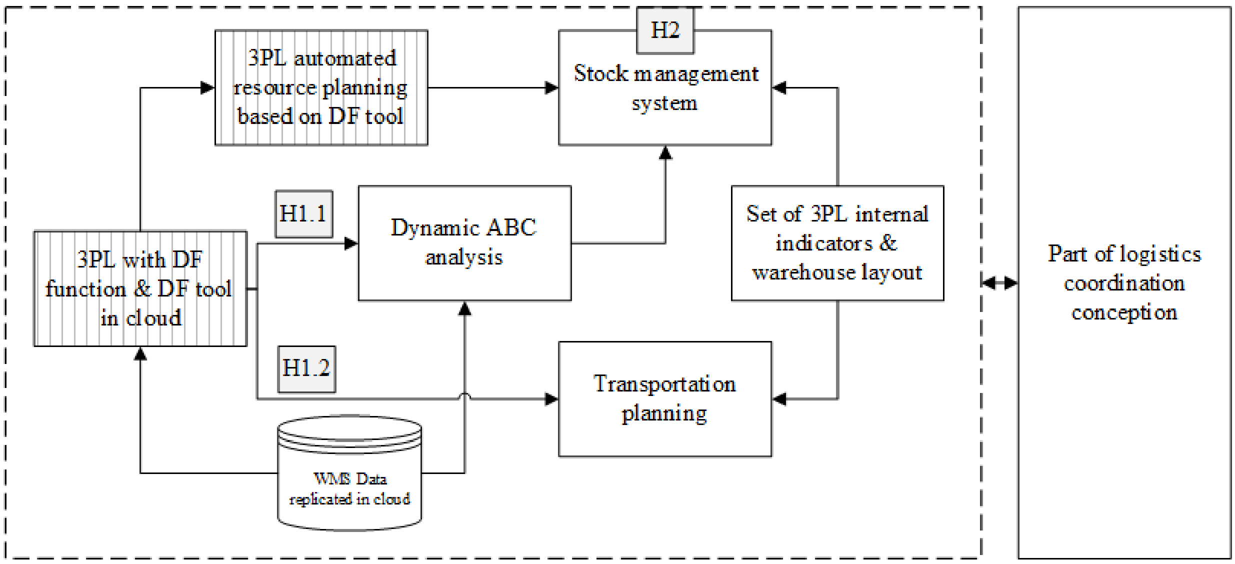

Figure 2. General research model.

The research model was created based on the previous work connected with examining the ability of 3PL to forecast. According to [3], a 3PL entity is able to possess the function of DF in the DN, and additionally, the quality of forecasts is one of the factors in logistics process coordination. Implementation of such a tool in the logistics company is also possible. For example, in [42], the authors showed considerations regarding the implementation of a DF tool in the logistics company, but with the usage of stationary hardware infrastructure. However, in [45], the authors showed an extension of this conception connected with the usage a cloud-based DF tool, with the additional simulation model of warehouse resource planning process improvement. The presented methodology was based strictly on WMS data replicated in a cloud system. The usage of innovative technology connected with data transformation could lead to achieving a sustainable system with high-performance indicators [46]. The achieved results make provide a direction for further research in the context of chosen parts of logistics coordination conception—inventory management and stock management. These two areas were examined according to coordination in the DN based on 3PL operational work and it provided the opportunity to develop two hypotheses:

Hypothesis (H1). *The demand forecasting tool supports the elements of logistics coordination in the distribution network through 3PL.*

Additionally, because of the hypotheses complexity, H1 was divided into two sub-hypotheses:

Hypothesis (H1a). *The demand forecasting tool used in 3PL supports the inventory management and assortment analysis.*

Hypothesis (H1b). *The demand forecasting tool used in 3PL supports the transportation planning process.*

Hypothesis (H2). *The 3PL entity is able to reduce the picking time in the warehouse by using a demand forecasting tool.*

A proper forecasting system, which ensures sufficient accuracy, could support the coordination of operations between sellers [47] and even in the wider parts of supply chains [48]. What is worth noting is that there are no studies that consider strictly the issue of supporting logistics coordination based on forecasts provided by 3PL. Verification of H1 will consist of checking the influence of the cloud-based DF tool on the chosen factors connected with logistics coordination itself. The author chose to consider, in this paper, only two of the mentioned factors: inventory management and transportation planning. Because of that fact, H1 will be divided into two sub-hypotheses—first connected with examination of influence on inventory management and second on transportation planning. The second hypothesis (H2) is connected with checking the possibility of stock management operation automation by the 3PL entity in DN. The issue of supporting the picking operations in the warehouse by DF solutions is usually considered from the retailer's operations [49] or predicting the workforce demand [50]. In this paper, this issue will be considered as a possibility of time reduction by modifying the current stock analysis method.

4. Methods

The methods used in the following paper are shown in Figure 3. Methods are presented with the main research steps, which need to be performed to verify the settled hypotheses.

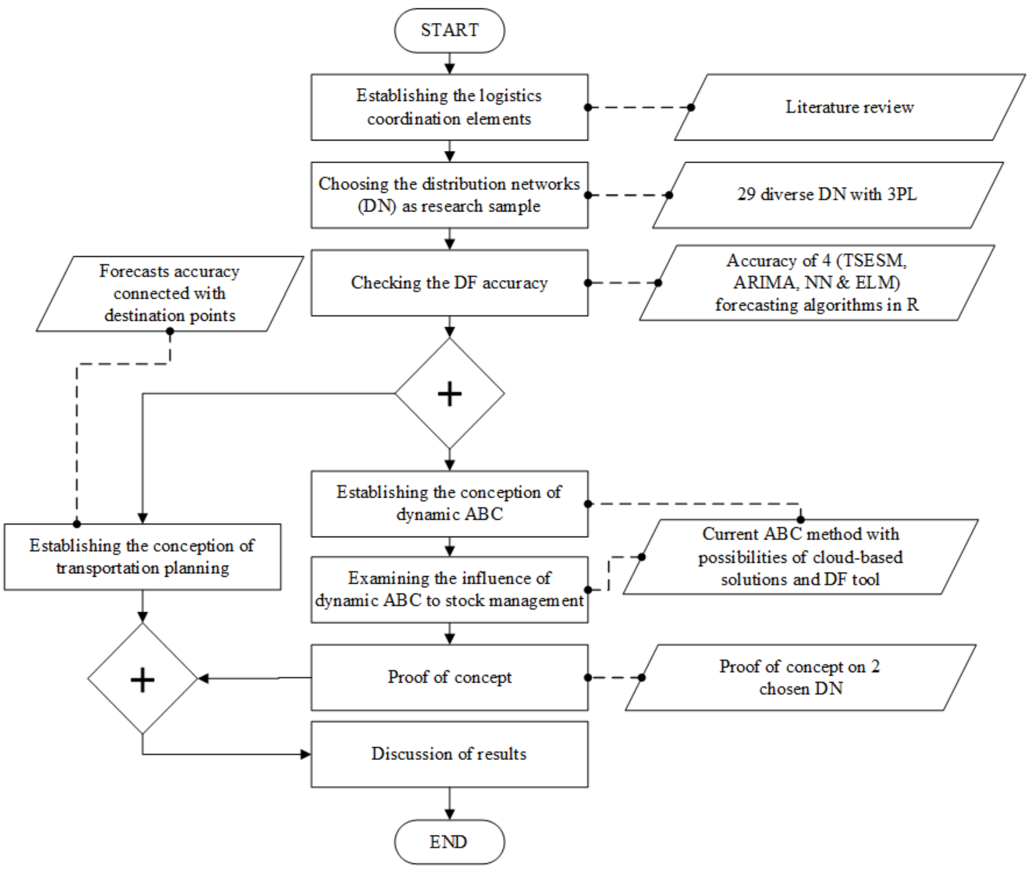

Figure 3. Research steps.

The first step in the research was shown in the first part of the article. The literature analysis allows for providing the most important information about logistics coordination based on 3PL entities' current and future activity. For further analysis, the author took into account two aspects connected strictly with the operational activity of 3PL—inventory management and transportation planning.

The second step was about choosing the DN to further analyze. The author wanted to choose diverse types of DN to test the further results in a wide range of cases. The main requirements connected with DN consideration were the existence of the node in 3PL in the DN structure and the fact of a manufacturer using 3PL to outsource logistics activities. The general specification of the chosen DN is shown in Table 2.

Table 2. Brief description of chosen DN.

DN Number	Brief DN Products Description	DN Products General Type (Food, Non-Food, Specific)	Do the Forecasts are Provided by Manufacturer?	Size of DN (Acccording to the Number of Products and DN Range)
DN_01	Pastas and sauces.	Food	yes	2
DN_02	Meat products.	Food	no	1
DN_03	Sweets and snacks.	Food	no	2
DN_04	Cosmetics and care products.	Non-food	yes	3
DN_05	Sweets and chocolate bars.	Food	no	1
DN_06	Cosmetics	Non-food	no	1
DN_07	Beverages, sweets, jellies.	Food	no	3
DN_08	Tobacco products.	Non-food	yes	2
DN_09	Tobacco products.	Non-food	no	2
DN_10	Pharmaceuticals	Specific	yes	2
DN_11	Sweets and chocolate bars.	Food	yes	3
DN_12	Cleaning products	Non-food	no	1
DN_13	Healthy beverages	Food	no	1
DN_14	Products for infants	Food	no	1
DN_15	Beverages	Food	no	1
DN_16	Healthly and bio food	Food	no	2
DN_17	Labeling and packaging infrastructure	Non-food	no	1
DN_18	Construction products	Non-food	no	2
DN_19	Cosmetics and cleaning products	Non-food	yes	3
DN_20	Sweets and chocolate bars.	Food	no	3
DN_21	Electronic products	Non-food	no	1
DN_22	Electronic products	Non-food	no	1
DN_23	Pharmaceuticals	Specific	no	2
DN_24	Pharmaceuticals and cosmetics	Non-food	no	2
DN_25	Pharmaceuticals and cosmetics	Non-food	no	2
DN_26	Electronic products	Non-food	no	1
DN_27	Fashion products and toys	Non-food	yes	3
DN_28	Furnitures	Non-food	no	1
DN_29	Cosmetics	Non-food	yes	2

The paper examined 29 DNs, which handle the variable streams of material goods. Mentioned DNs were also grouped into three general groups: food, non-food and specific. Additionally, the table shows the classification according to number of products and DN range, called the DN size. Grouping was conducted by the author in an arbitrary manner following the below logic:

- "1" means that the manufacturer in this DN is an average enterprise with range of activity at the country level.
- "2" means that the manufacturer in this DN is an average or big enterprise with the range of activity at the international level.
- "3" means that the manufacturer in this DN is a big enterprise with the range of activity at the international level and is a well-known brand.

Last information shown in the Table 1 is connected with the information sharing rules in the particular DN. Information about sales or production forecasts is shared in 27.59% of cases.

In the next step, the forecast accuracy was checked based on forecast calculation supported by R solutions (Figure 4).

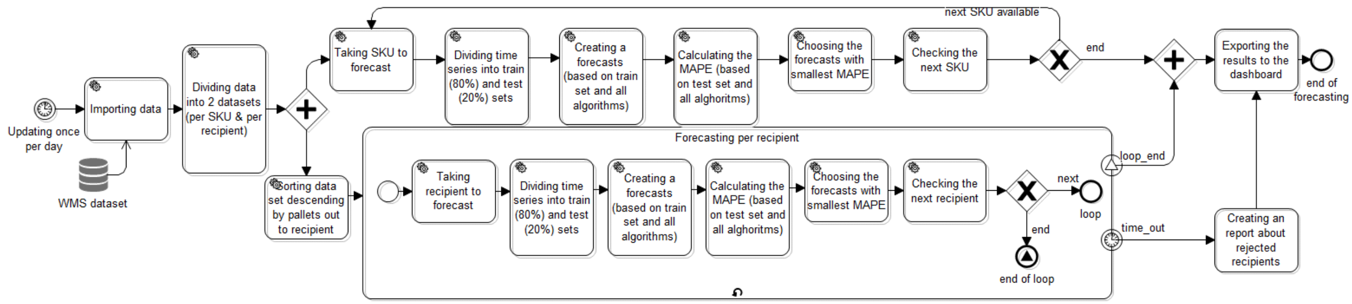

Figure 4. Forecasts accuracy calculation process in BPMN 2.0.

The process of forecasting takes place during the implementation of the previously mentioned DN. It starts automatically, every day at the established time. After that, the data are imported from WMS (Warehouse Management System) and replicated in the cloud. Because the quantity of data is high, and the quality of the logistic service and other operations has to be high, WMS must integrate with other information technology solutions [51]; in this case, this is cloud-based databases. Data consist of the following information: SKU (Stock Keeping Unit), date and type of movement, the quantity of released boxes from the picking process, point of destination and information about palletization. The length of time series depends on the particular DN and it can be different, but usually, the data history is from 5 months to 1.5 years. DF tool has the option to create two types of forecasts: per SKU and per recipient. The first type (per SKU) is the forecast created based on daily information about the released quantity of boxes and the second one (per recipient) is about the information connected with the point-of-delivery destination and quantity of pallets (in the EUR1 to calculate the predicted load space occupancy). Time series to forecasts are divided into two parts: train and test. A training set consists of 80% of the whole time series and it is needed for calculating the forecast and testing set (the rest of the time series) is the set where the adjusting of trained algorithms is tested—the whole process is repeated for each SKU and point of destination. The forecasts are created in 30 days horizon and based on algorithms connected with time series exponential smoothing methods (TSESM), automatically created ARIMA (autoregressive integrated moving average), simple artificial neural network (ANN) and extreme learning machine (ELM)—brief characteristics of the mentioned algorithms are shown in Table 3. The choice of mentioned methods was indicated by the current market, where the top algorithms for demand forecasting are the methods based on ARIMA [52], machine learning [53] and neural networks [54]. However, there are a lot of traditional methods connected with time series exponential smoothing [34], which are well known and have been used in forecasting systems for a long time.

The forecasts are calculated for each of the chosen algorithms (Table 3) for each SKU and recipient and the final choice of forecasts depends on the minimum value of MAPE in the test set (the logic of accuracy calculation and best-fitting algorithm selection are shown in Figure 3). In the case of forecasts per SKU, forecasting loop ends in the case of reaching the forecast to all SKU. On the other hand, in the case of forecasts per recipient, the forecasting loop ends in the case of reaching the forecasts to all recipients or in the case of exceeding the calculation time. In this second option, the forecasts are calculated only for the most important recipients.

Forecasts are treated as input for transportation planning and stock management. For transportation planning, the results of the forecasts are supported by the additional information about particular logistics parameters, such as pallet dimension and weight. Forecasts per recipient are created based on pallet quantity and, in this case, this unit is changing to planned pallet locations to send to the particular recipients.

Forecasts connected with stock management are forecasts in the SKU units and they are treated as an input for ABC analysis. A whole stock management system is established in the cloud and the general logic of its conception and way of forecasts usage is shown in Figure 5.

Table 3. Brief description of chosen forecasting algorithms.

Algorithm	Functions in R Software	Function Arguments	Source Library in R	Brief Description
TSESM	1. ses(y, h = . . . , level = c(. . . , . . .), initial = c(. . . .), alpha = ..., lambda = ..., biasadj = . . .) 2. holt(y, h = ..., damped = . . . , level = c(. . . , . . .), initial = . . . , exponential = ..., alpha = . . . , beta = . . . , phi = . . . , lambda = . . . , biasadj = . . .) 3. hw(y, h = . . . , seasonal = c(. . .), damped = . . . , level = c(. . . , . . .), initial = c(. . .), exponential = . . . , alpha = . . . , beta = . . . , gamma = . . . , phi = . . . , lambda = . . . , biasadj = . . .)	y—time series, h—horizon, level—confidence level, initial—selecting the initial state values, alpha, beta, gamma—value of smoothing parameters if NULL it will be estimated, damped—if TRUE then use a damped trend, phi—value of damping parameter, exponential—if TRUE then exponential trend is fitted, seasonal—type of seasonality: additive or multiplicative	library(forecast)	Usage of simple exponential smoothing method—Brown (ses), Holt (holt) and Winters (hw). The final choice of an algorithm is done by comparing the minimal MAPE in testing set.
ARIMA	auto.arima(y, d = . . . , D = . . . , seasonal = . . . , ic = c(. . .), lambda = . . .)	y—time series, d—order of first differencing, D—order of seasonal differencing, seasonal—if FALSE restrict a search to non-seasonal models, ic—information criterion to be used (aicc, aic or bic), lambda—Box Cox transformation parameter	library(forecast)	Usage of ARIMA model with automatically chosen parameters and information criterion.
ANN	nnetar(y, p, P = . . . , repeats = . . . , lambda = . . .)	y—time series, p—embedding dimension for non-seasonal time series, P—number of lags used as inputs, repeats—number of networks to fit with different random starting weights, lambda—Box Cox transformation parameter	library(forecast)	Usage of simple artificial neural network with one hidden layer and lagged inputs.
ELM	elm(y, m = . . . , hd = . . . , type = c(. . .), reps = . . . , comb = c(. . .))	y—time series, m—frequency of time series, hd—number of hidden nodes, type—estimation type for output layer weights (could be lasso, ridge or step), reps—number of networks to train, comb—when reps > 1 then combination operator for forecast (could be median, mode or mean)	library(nnfor)	Extreme Learning Machines (ELM) is a function from the package nnfor which serves as an automatic, semi-automatic, or fully manual modeling of artificial neural networks for time-series forecasting.

Source: own elaboration based on [55].

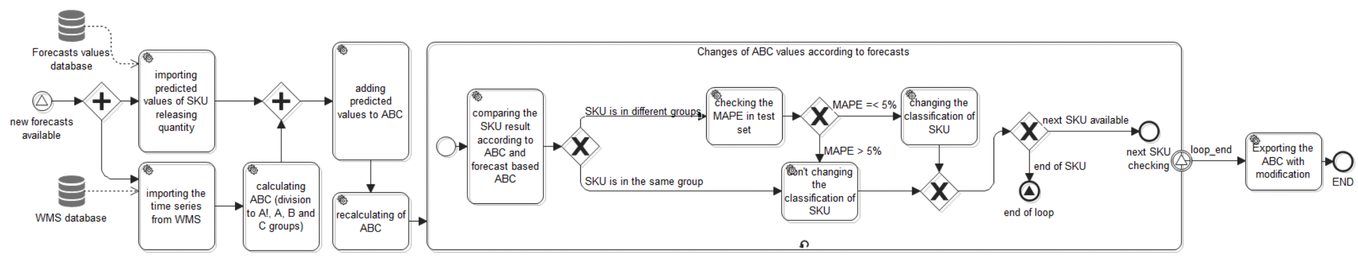

Figure 5. ABC results from modification based on forecast process in BPMN 2.0.

Analysis of ABC is created in the traditional way (by calculating the shares of a particular SKU in the releases from the warehouse), but with a special distinction of an additional group:

- A!—the SKU with special care with shares at the level of 25%.
- A—the SKU with shares in total releasing at a level from 25% to 80%.
- B—the SKU with shares in total releasing at a level from 80% to 95%.
- C—the SKU with shares in total releasing at a level from 95% to 100%.

In the next step, whole SKU is checked for the possibility to change the classification group's point of view. If there is an option to classify SKU differently according to forecast results then the accuracy of created forecasts in the test set is checked. If the accuracy (according to MAPE) is equal to or lower than 5% the SKU is located in the new group. After finishing the creation of groups, the result is exported and could be used to replace goods in different locations in the warehouse to plan the warehousing processes more properly. The idea of using the forecasts to improve the ABC analysis and stock management system of 3PL will be tested in the two chosen DNs to show the proof of concept.

5. Results

The average forecast errors were calculated based on average MAPE. To simplify the presented results, firstly, the MAPE was calculated for each SKU in the weekly horizon for 5 weeks. Next, the average values of MAPE were calculated for each week and at the end of the whole period. These results are shown in Table 4. Results were calculated based on data from a cloud-based system where the WMS databases are replicated. The data consist of releasing quantities of particular SKU (in boxes), the ID number of SKU, SKU name, destination point (city and postal code) and timestamp (day and hour, aggregated to daily data in the DF tool). Data reflect the quantities of 3PL entities' warehouse output quantities (releasing to the next nodes in DN).

According to Table 4, the average forecast error per SKU is equal to 22.17% (median equal to 22.50%) and per recipient is equal to 21.50% (median equal to 26.24%). There are no strong correlations (Pearson indicator > 0.8) between any variables that occurred. It is just an average correlation (about 0.425) between forecast accuracy to SKU and recipients. It could mean that there are some relatives between the DF tool running in the different specific sets of data and there is a probability of expecting similar results. It could be a piece of important information for future activities of 3PL, which could expect similar results of forecasting accuracy in the different activities. There is no huge forecast error dispersion in the case of different DN sizes and types (Figure 6) and some single protruding results could be treated as outliers.

Table 4. Average forecast errors for each DN.

DN Number	Average Forecasts Error for SKU	Average Forecasts Error for Recipient	DN Number	Average Forecasts Error for SKU	Average Forecasts Error for Recipient
DN_01	23.64%	45.11%	DN_16	20.83%	19.25%
DN_02	77.67%	26.99%	DN_17	8.64%	4.85%
DN_03	5.15%	2.72%	DN_18	24.73%	36.21%
DN_04	1.73%	36.11%	DN_19	6.19%	8.07%
DN_05	27.28%	2.61%	DN_20	32.83%	27.18%
DN_06	3.97%	26.99%	DN_21	27.30%	39.43%
DN_07	28.25%	37.99%	DN_22	23.96%	26.24%
DN_08	13.92%	2.87%	DN_23	38.25%	31.92%
DN_09	6.09%	1.22%	DN_24	18.82%	5.73%
DN_10	36.71%	34.43%	DN_25	2.40%	6.08%
DN_11	28.48%	34.10%	DN_26	20.78%	8.73%
DN_12	10.24%	37.71%	DN_27	22.73%	18.73%
DN_13	38.75%	37.74%	DN_28	15.36%	12.73%
DN_14	16.26%	2.89%	DN_29	39.36%	45.60%
DN_15	22.50%	3.22%			

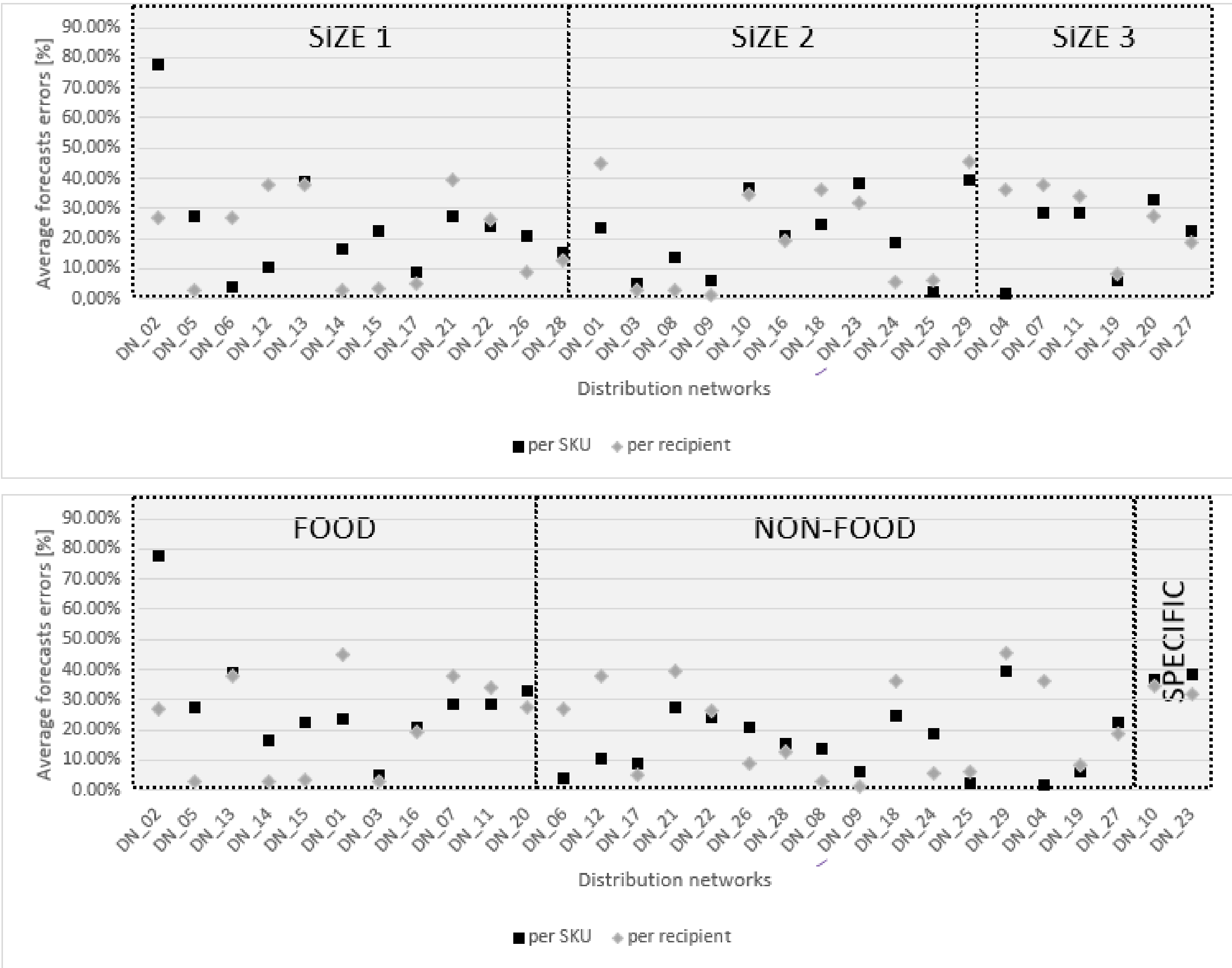

Figure 6. Average forecast errors in the particular DN sizes and types (food, non-food and specific).

Despite the repeatability of the results, the non-food DNs are the most forecasting-friendly networks from the perspective of forecasts created by 3PL (Table 5) and the worst ones are the specific DNs. The reason for that is the lack of sufficient information exchange between nodes in DNs and the high influence of promotional and different factors, which should be exchanged with 3PL to improve the forecasting system. The size of DNs generally do not influence positively or negatively on the 3PL forecasting system—the one exception is the forecasting system per recipient in the large DN (size 3). The reason for usage is the huge amount of customer data and large, hardly predicted participants in these DNs, meaning the forecast results are worse.

Table 5. Average and medians for forecasts errors in each DN size and type.

DN Attribute	Average Value Forecasts		Median Value Forecasts	
	per SKU	per Recipient	per SKU	per Recipient
Food	29.24%	21.80%	27.28%	26.99%
Non-food	15.39%	19.83%	14.64%	15.73%
Specific	37.48%	33.17%	37.48%	33.17%
Size 1	24.39%	19.17%	21.64%	19.48%
Size 2	20.90%	21.01%	20.83%	19.25%
Size 3	20.04%	27.03%	25.49%	30.64%

Therefore, the 3PL enterprise is able to create the demand forecasts at different levels of aggregation (per SKU and per recipient). Forecasts per recipient could be used as an input for transportation planning process, especially when the forecasts will be additionally aggregated to a particular geographical region. As a result, 3PL is able to provide the early information about the future demand in the individual areas of distribution in the assumed demand unit, such as EUR pallets.

An example dashboard could show the predicted demand information in EUR pallet quantities in the region of Poland. Thanks to this kind of solution, the 3PL is able to evolve information about forecasts into knowledge about transportation demand. H 1b could be confirmed and because of this, H 1 could be also confirmed. It also means one can improve the transportation fleet, making it more efficient and increasing their sustainability level through better planning in terms of future movement. Similar conceptions, which connect forecasting with transportation planning from the perspective of 3PL, are already considered in the literature [34], but usually, these kinds of consideration focused only on the near range of activity.

Usage of such a DF tool in the perspective of inventory management based on modified ABC analysis (Figure 5) allows for analyzing the possibility of H 1a confirmation. Additionally, in this paper, the possibility of inventory management support and its automation were checked by a short proof of concept, connected with the pilot implementation of an inventory management tool based on the cloud DF tool in two chosen DNs. The author, based on practical requirements supported by industrial experts' opinions, chose DN.19 and DN.25 to test this solution. In both, DN assortment planning has a key role because of the e-commerce activity, which includes:

- In the case of DN.19, about 35% of manufacturer distribution activity occurs in the warehouse space managed by 3PL (the rest of the activity is connected with homogeneous pallet flow).
- In the case of DN.25, whole manufacturer distribution activity occurs in the warehouse space managed by 3PL.

The choice of the e-commerce part in 3PL activity is of huge importance and difficulties in the picking process are addressed (in the comparison with different types of activities). Detailed specifics of the mentioned DN are shown in Table 6.

Table 6. Detailed specifics of DN.19 and DN.25 in the ABC analysis.

DN	E-Commerce SKU Quantity	Identified ABC Unit
DN.19	501	Picked boxes
DN.25	41,627	Order lines

The data range used in this analysis is the same as in the case of the DF tool. The ABC unit shows the analysis and helps draw conclusions about changing the assortment location in the warehouse, established with operational managers in the particular warehouses. Units connected with picked boxes relate to how many boxes of a particular SKU were picked to fulfill the order. Order lines are an indicator that allow answering the question of how many orders were commissioned to pick in the particular SKU. According to the mentioned conception of modification in the traditional ABC by forecasting data and real-time data from the cloud, the analysis was conducted. The example result dashboard is shown in Figure 7.

In both cases (DN.19 and DN.25), the potential of ABC usage in inventory management (warehouse location establishment) is visible. In the case of DN.19, only 1% of SKU generates about 19% of picked boxes, and in the case of DN.25, about 0.64% of SKU generates about 20% of order lines. ABC analysis is well-known analysis, but it still has some updated and new approaches to calculate it or conclude the results. Contemporary solutions and methods are still connected with ABC [38]. Based on ABC analysis (proposed by the author), supported by forecasts and the current stream of data, the decisions connected with SKU and labor relocations could be made. Gathering the information about the warehouse releasing quantity or planned orders in advance provides the opportunity for better SKU allocation and better planning of resources in the warehouse. The tested solution was compared to current inventory management solutions in DN.19 and DN.25 according to the chosen KPI (Key Performance Indicator). The chosen KPI was the average quantity of picked boxes (or parts) in one shift (Table 7).

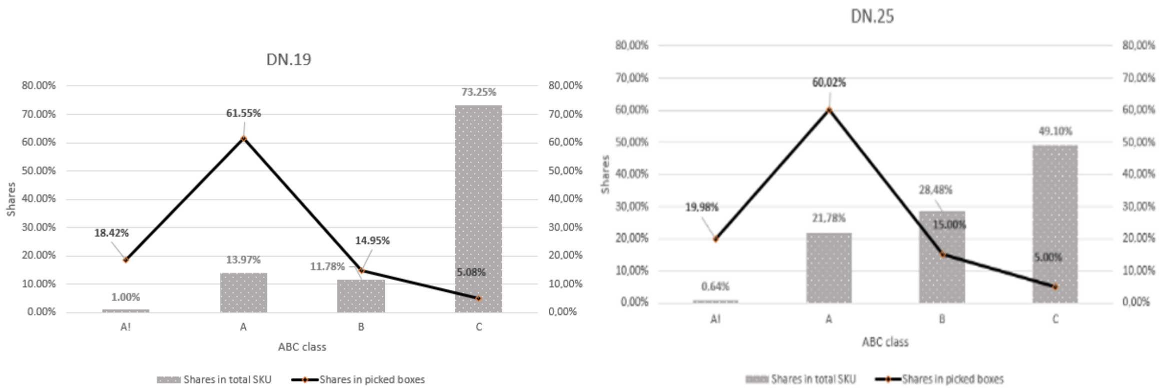

Figure 7. "Future" ABC dashboard.

Table 7. Chosen KPI.

Equation	Brief Description
$\mathrm{KPI}_1 = \sum\left(\frac{x}{y} \times \frac{1}{S}\right)$	KPI_1—chosen indicator for one month x—quantity of picked boxes (or parts) per day y—number of workers per day S—number of shifts per day

According to the conducted pilot, KPI_1 in the case of:

- DN.19, on average, increased by 2%;
- DN.25, on average, increased by 3.5%.

The indicator was calculated for a period of three months and the increase or decrease level was calculated according to the average value of this indicator from a mentioned period in comparison to the base value (calculated by 3PL management). The increasing value of the indicator means that in one shift, a worker is able to pick more boxes (or parts), so there is a possibility of reducing the picking time by using an ABC analysis supported by considerate conception and it is also an opportunity to confirm H2. There is also a common approach to adding the forecast results to ABC analysis in the form of XYZ analysis [56], but according to the author's opinion, the modification of ABC results based on forecast results will be more prospective in the case of logistics coordination in DN.

6. Discussion

The proposed methodology and tool could lead the 3PL to create a lot of benefits for manufacturers and the whole DN.

Similar accuracy in the presented DF tool for different types of DN.

The proposed forecasting tool obtains similar results (with a similar level of errors based on assumed indicators). Achieving repeated results creates a possibility of more free use and implementation of such a tool in a wide range of DNs. The possible benefits for the DN or manufacturer, which would like to develop cooperation with 3PL in this way, could be easily estimated based on results from the already tested networks. Achieving similar results also provides knowledge about the limitation of algorithms that were used for calculation. To achieve better results, it will be necessary to provide more accurate input data or change the information flow logic in the network.

Tendency to generate better accuracy for non-food material flows.

Despite the similar results for all considered DNs, there is a tendency to achieve better accuracy for non-food SKU in DNs. This fact is due to the lesser complexity of such a flow (usually for food and special products flows, there are some additional variables, such as expiry date or legal regulations). This result also implicated the necessity of creating a better information flow with logistics service providers. For achieving better accuracy and creating a wider possibility for logistics coordination, it could use products or destination point segmentation [57].

Possibility of different level data aggregation.

Data aggregation at different levels (per SKU, per recipient, per POS) provides the chance to create different types of plans (based on different kinds of forecasts). In this way, a 3PL entity is able, for example, to support the transportation planning and inventory management for a manufacturer or even for the whole DN. There is also a possibility to support the current actions of 3PL in the area of transportation issue forecasting [39] by providing more extended information and overlook on the other nodes in the network. In the presented case, the 3PL is able to provide the plans for transportation in EUR pallet quantity, providing managerial information about the load for particular destination points. Further, 3PL is also able to support the inventory management in the DN, where the proper inventory management provides the better performance of distribution actions [58]. In the presented case, 3PL is able to support inventory management by providing necessary information to warehouse analysis and create future ABC analysis.

Support for e-commerce activities.

Proper inventory management could also provide proper performance in multichannel distribution cases [59]. On the other hand, demand forecasting and planning could be transformed into omnichannel reality [60] by using proper data handling. In the presented paper, the author showed the issue of support inventory management for e-commerce DN. Usage of demand forecasting and logistics coordination issues—including 3PL—provides the possibility of improving stock analysis and achieving better KPI in the area of supporting e-commerce activity by 3PL.

Possible influence on sustainability.

Logistics operations, such as transportation and improper material handling, have a strong influence on dismissing the sustainability goals in enterprises [61]. On the other hand, the integration of logistics operations in the supply chain could improve the negative effect of logistics operations on the environment and social life [62]. Therefore, according to the main assumption of logistics coordination, there is some rationale for looking for the influence of logistics coordination on sustainability. If the logistics activities will be planned by an enterprise that provides value and is an expert in handling material and information flows, the negative impact of logistics (caused by, for example, wrong last-mile deliveries concepts, wastes inflows and empty runs of transportation units) could be reduced.

According to the presented paper, 3PL is able to take the function of logistics coordination in the case of transportation planning and inventory management.

7. Conclusions

During consideration of the proper logistics coordination model, it was noticed that the most efficient model is the centralized coordination model with 3PL as a node responsible for logistics process coordination. The meaning of logistics processes and the huge experience and willingness to find new areas of services complementary to logistics process handling gives occasion to developing such a conception as an industrial reality. Coordination issues are usually considered with criteria of network configuration, including number of products, network structure and demand pattern, network planning features, such as general planning methodology and assumptions, and from the point of view of information–coordination, such as coordination mechanism and features [63]. In this case, there is a possibility to implement the DF tool to coordinate the material flows from the stock management and transportation planning point of view. It could be applied to different types of DN with similar forecast accuracy, which is possible to achieve. Further, 3PL is also able to fluently change the forecast aggregation level—for example, by creating calculations per SKU and per recipient. This provides a great opportunity to adjust the forecast results to particular situations and nodes in DN.

Forecast results were on a similar level of accuracy for the different types of DN, but some product types show a greater level of forecast friendliness. The best forecasts were created for non-food goods, so this could also be the first area to implement the solution connected with the 3PL coordination function. It could be assumed that the forecast's accuracy will be better if the information flow is improved. It is well known that the usage of new technologies in the logistics field reduces the risk in logistics networks [64] and improves efficiency in the field of efficiency and planning. The data, which are treated as an input to the DF tool and demand management system, are usually sensitive data (especially if the competitive retailers are involved in information exchange). In those cases, the information management system could be supported by, for example, nowadays, blockchain technologies [65] or more popular and less debatable solutions, such as EDI (Electronic Data Interchange). Further, 3PL does not have any direct benefits from sales, so the trust factor of other DN nodes could be higher than in the case of different enterprises. DF could support inventory management as input information for assortment analysis and warehouse operation planning. The whole DF tool support system could be easily visualized and could be treated as input data for supporting the software used in DNs. The digitalization aspect has a significant meaning because digitalization is one of the ways to adopt the 3PL activities to current market requirements connected, for example, with omnichannel distribution [66]. We are witnessing a similar situation in transportation planning, where 3PL is able to reach the necessary information in advance and try to plan the operational actions. It is quite a prospective solution, especially since, according to some authors, there are still some problems with transportation planning, such as last-mile deliveries to reach their efficiency potential [7]. The possibility of solving this kind of issue could be an area for further research.

The transfer of forecasts to coordination issues could be created by different forecast aggregation and different methods of data usage in operational, tactical and strategic levels. The pilot research proves that inventory management based on DF tool support could be automated by supporting and modifying ABC analysis by future data about material flows. It could also lead to an improvement in KPI connected with picking time, so the delivery process to a final customer could be shorter and more flexible. In the author's opinion, future research in the presented fields could be extended by:

- Examining the usage of presented DF, transportation support and inventory management tools in the context of process digitalization and building Digital Twins in DNs where the logistics operator provides the services.
- Improving the information flows between nodes in DNs by using current technologies, which provide high security for exchanged data (for example, blockchain technology).
- Examining the possibility of implementing additional technologies for inventory management (based, for example, on extended ANN [67] or in the conditions of Smart Production [68]).
- Checking the influence of logistics coordination on negative aspects of network coordination connected, for example, with the low level of flexibility.

The DF supports elements of logistics coordination for 3PL in DNs, such as inventory management and transportation planning. It is important from the point of view of logistics coordination because the entity with high skills in handling logistics processes could also obtain earlier information about demand and plan future actions earlier by sharing proper information with other nodes. The originality in this paper is to compare the new function of 3PL entities and demand forecasting, as an element of a logistics coordination construct. The 3PL is able to provide coordination issues from the perspective of inventory management and transportation planning in the DN. The author is also aware of research limitations. Firstly, it needs to be considered whether the 3PL, without the ability of demand forecasting, is also able to provide some actions connected with logistics coordination and there are still other factors (mentioned in a theoretical construct of logistics coordination) that need to be examined to provide full information about the possibility of transferring the function of logistics coordination to 3PL. What also needs to be considered is the calculation of the possible positive environmental impact of logistics coordination by better planning operations connected with logistics and reducing waste.

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Abbreviations

3PL	Third-party logistics
ABC	Inventory classification method by ABC
ANN	Artificial neural network
ARIMA	Autoregressive integrated moving average
BI	Business Intelligence System
BPMN 2.0	Business Process Modeling and Notation 2.0
DF	Demand forecasting
DN	Distribution network
EDI	Electronic Data Interchange
ELM	Extreme learning machine
KPI	Key Performance Indicator
LSPs	Logistics Service Providers
MAPE	Mean Absolute Percentage Error
R	R programming language
SKU	Stock keeping unit
TSESM	Time series exponential smoothing methods
WMS	Warehouse management system
XYZ	Inventory classification method by XYZ

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