



RANKING OF INTEGRATION FACTORS WITHIN SUPPLY CHAINS OF FORWARD AND BACKWARD TYPES - RECOMMENDATIONS FROM RESEARCHES

Bernd Hentschel¹, Roman Domański², Michał Adamczak², Piotr Cyplik², Łukasz Hadaś², Martyna Kupczyk², Żaneta Pruska²

¹) BERLINOXX Projektzentrum Logistiknetzwerke, **Germany**, ²) Poznan School of Logistics, Poznan, **Poland**

ABSTRACT. Background: Integration trends are one of main determinants of the development of modern logistics. After the period of interest focused mainly on supply chains realizing one-way flows only, at present there is a time for supply chains characterized by two-way flows, realizing at the same time both forward and backward flows. The possibility of various configurations of such chains requires identification of integration factors and determination of their influence on the results of the whole supply chain. Experiences of the science as well as the practice of supply chains show the urgent need of learning of reasons of the integration within supply chains of the two-way type.

Material and methods: The researches on modeling and simulation of integration processes within supply chains of forward and backward type were carried out in the environment of iGrafx Process 2013 for Six Sigma. The empirical material obtained in these researches was put to the statistical analysis by the used of Minitab 17. The identification of the significance of differences was made with the help of analysis of variance ANOVA. Additionally the analysis of differences in form of absolute averages was made. The following measures are main ones for the evaluation of the integration of a supply chain of forward and backward types: cashflow, profitability, service level.

Results: 8 192 simulation experiments were made for 6 integration factors: accessibility of recycled materials, production planning, stock management, integration of transport, unification of packing materials and optimization of the material flow. Based on the analysis of the significance and values of differences, the results of the influence of each integration factor on global results of supply chains of forward and backward type were obtained. They were used to prepare the ranking of integration factors. The main factors, forming the integration shape of two-way supply chains were: stock management, production planning and accessibility of recycled materials.

Conclusions: The integration offers new possibilities therefore it is the promising option of actions. In complicated and complex logistic reality, it is more and more difficult to function, in economic sense, without starting and tightening close cooperation. Sometimes it is even not possible at all. The growing popularity of two-way supply chains opens the dimensions of the possible cooperation. However, both science and the practice need the reliable quantitative information covering the conscious creation of the integration in supply chains. Such tool could be a ranking, recommended in this paper, of integration factors from the perspective of three measures of evaluation of global level of functioning of the supply chain.

Key words: ranking of integration factors, modeling and simulation of the supply chain, measure of the supply chain.

INTRODUCTION

The integration solutions, due to the possible opportunities, are the objects of interest both for science and practice already

for a long time [SCOR 2010]. The identification of pro-integration factors, learning the strength and the direction of their influence within the defined configurations of supply chains as well as the creation of the system of evaluation of the integration level

[Aryee, Naim, Lalwani 2008; Lummus, Vokurka, Krumwiede 2008, Dobrzyński 2009] are the basic problems, still waiting to be solved. These solutions are awaited both by the science and by the practice. The present world suffers from the shortage of resources, and tries to rationalize the use of them [Mousumi 2010]. The actions covering the use of recycled materials change the paradigms of thinking and in a natural way bring companies closer in various dimensions - integration relationships. The supply chains of forward and backward type (two-way) are the intensively developing area of the logistics [Cardoso, Ana Paula, Barbosa-Povoa, Relvas 2013; Jonrinaldi, Zhang 2013], which needs to be researched in more detailed way. It is worth to make a scientific research of the integration phenomenon in the context of the paradigm of the sustainable development (eco-logistics) to be able to use offered effects in an intended way [Zaman, Goschin 2010].

RESEARCH PROCEDURE - REVIEW OF LITERATURE

The essence of the research project was a comprehensive identification of both internal and external factors, which influence on the shape of the integration of supply chains of forward and backward type. The plan of the research projects consisted of the following tasks:

- identification of potential integration factors based on the review of the literature,
- selection (listing, comparison and choice) of integration factors based on questionnaire researches conducted in companies,
- elaborating, based on theoretical and practical researches, the integration levels (A, B, C, where A means the highest one) within each of the factors - defined characteristics of actions,
- identification of methods of measurement and evaluation of the integration level based on the review of the literature,
- elaborating, based on theoretical and practical researches, indicators of the evaluation of the integration level of two-way supply chains,

- determination of the direction and the strength of the influence of integration factors with the help of modeling and simulation procedure.

The topic of integration factors is covered among others in the following works:

- evaluation of the influence of integration factors on the efficiency of the production planning [Malak, Adamczak, Domański, Cyplik 2013],
- pointing the most essential integration factors as well as the actions undertaken to build closer relationships with cooperation partners within supply chains [Kupczyk, Pruska, Hadaś, Cyplik 2014],
- presentation of similarities and differences in actions undertaken to increase the integrations in two-way supply chains [Kupczyk, Hadaś, Cyplik, Pruska 2014].

The topics of indicators and the evaluation system were the subjects of among others following works:

- system of measurement of the integration level of a supply chain of forward and backward type, together with the describing of the rule of the evaluation as well as the guidelines for the transformation of the chain in order to increase its efficiency [Hadaś, Cyplik, Adamczak 2014],
- the system of measurement of the integration level of sustainable supply chain together with its methodology and guidelines of its application [Cyplik, Hadaś, Adamczak, Domański, Kupczyk, Pruska 2014].

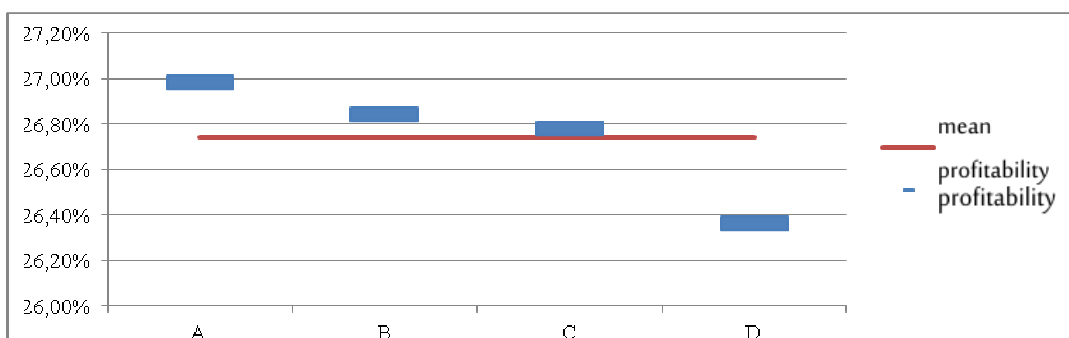
The idea of present researches has its source in previous scientific works of authors [Adamczak, Domański, Cyplik, Pruska 2013]. The results of previous introducing researches were already presented in the paper [Domański, Adamczak, Hentschel 2015]. The present article gives the whole results of researches of authors.

ANALYSIS OF THE INFLUENCE OF INTEGRATION FACTORS

Introduction to analysis

Based on the results of the conducted simulations within the model of the supply chain of forward and backward type, the authors observed various influence of individual integration factors on the defined operational indicators (cashflow, profitability,

service level). Such observation can be used to build a ranking of integration factors that means to indicate which factor influences in the biggest way on given operational indicators. Authors based their conclusions on the analysis of variance between values of given indicator on each of integration level of each factor and a global mean of this indicator (calculated for all integration levels). The example of such situation is presented on Figure 1.



Source: own study

Fig. 1. Comparison of the profitability of supply chain at various integration levels for the factor Production planning
Rys. 1. Porównanie rentowności łańcucha dostaw na różnych poziomach integracji czynnika Planowanie produkcji

Taking into account the number of integration factors (6), the number of integration levels for each of factors (4) and the number of replications (2), which were implemented in the researches, the differences were calculated for the total number of 8 192 cases. They created the database for the use of building the ranking of integration factors. Firstly, it was decided to conduct the analysis of significance of individual differences to eliminate observations without differences from statistical point of view. Authors assumed that the bigger change of the integration level within considered factor induces bigger change (difference) of an indicator of a supply chain, the more significant this integration factor is. The ranking of integration factors was prepared in two variants: based on the influence on each of defined indicators and on the mean value of the influence. The detailed analysis were made and presented in subsequent parts of this work.

Analysis of the significance of differences

The aim of the analysis of the significance of differences is to determine whether the values of the definite indicator for the given factor at separate integration levels are significantly different comparing to the mean value of this indicator from statistical point of view. Authors assumed, that if there are no significant differences between values at individual integration levels, it means that these values are not significantly different from the global mean value of this indicator. The following hypotheses were stated:

H0: Values of differences of definite indicator from its mean value for each integration level are the same,

H1: Values of differences of definite indicator from its mean value for each integration level are not the same.

The verification of stated hypotheses was conducted by the use of ANOVA analysis of

variance. The significance level $\alpha=0,05$ was assumed. The example of the report of ANOVA analysis of variance obtained by the use of Minitab 17 is presented below (the example prepared for the analysis of the

profitability for the factor: Production planning).

| Analysis of Variance | | | | | |
|----------------------|------|---------|----------|---------|---------|
| Source | DF | Adj SS | Adj MS | F-Value | P-Value |
| Planning level | 3 | 0,04345 | 0,014483 | 44,26 | 0,000 |
| Error | 8188 | 2,67944 | 0,000327 | | |
| Total | 8191 | 2,72289 | | | |

Table 1. Values of P-Value indicator
Tabela 1. Wartości wskaźnika P-Value

| Factor | P-Value | | |
|------------------------------------|----------|---------------|---------------|
| | Cashflow | Profitability | Service level |
| Accessibility of recycled material | 0,000 | 0,000 | 0,000 |
| Production planning | 0,000 | 0,000 | 0,000 |
| Stock management | 0,000 | 0,000 | 0,000 |
| Transport integration | 0,846 | 0,000 | 0,992 |
| Unification of packaging | 0,998 | 0,645 | 0,932 |
| Optimization of material flows | 0,001 | 0,000 | 0,003 |

Source: own study

The ANOVA analysis was made for six distinguished integration factors separately for each of indicators. Therefore, 18 analyses were obtained. The P-values for them were presented in Table 1.

According to assumptions of ANOVA analysis, if the value of P-value indicator is bigger than assumed significance level, there are no reasons to reject the null hypothesis. The grey color was used in the table 1 for these values, which do not allow to state, that at given integration levels the values of definite

indicator are different comparing to its global mean value.

Analysis of values of differences

The second step of realized analysis was to determine differences between mean values at definite integration level of each factor and a global mean value of this indicator. The values of differences for three indicators of supply chains are presented in tables 2-4. The values, which are not significantly different from global mean from statistical point of view, are marked by the used of grey color.

Table 2. Values of differences of indicator Cashflow from its mean value
Tabela 2. Wartości różnicy miary cashflow od jej wartości średniej

| Integration level | Accessibility of recycled material | Production planning | Stock management | Transport integration | Unification of packaging | Optimization of material flows |
|--------------------------|------------------------------------|---------------------|------------------|-----------------------|--------------------------|--------------------------------|
| A | - 55 883,00 zł | 382 092,00 zł | 704 694,00 zł | 10 063,00 zł | 2 239,00 zł | 38 763,00 zł |
| B | - 30 041,00 zł | - 54 645,00 zł | 286 791,00 zł | 1 740,00 zł | - 115,00 zł | 23 365,00 zł |
| C | - 16,00 zł | - 84 207,00 zł | 56 956,00 zł | - 2 661,00 zł | - 507,00 zł | - 23 020,00 zł |
| D | 85 940,00 zł | - 243 240,00 zł | -1 048 441,00 zł | - 9 142,00 zł | - 1 617,00 zł | - 39 108,00 zł |
| Mean absolute difference | 42 970,00 zł | 191 046,00 zł | 524 220,50 zł | 5 901,50 zł | 1 119,50 zł | 31 064,00 zł |

Source: own study

Table 3. Values of differences of indicator Profitability from its mean value
 Tabela 3. Wartości różnicy miary rentowność od jej wartości średniej

| Integration level | Accessibility of recycled material | Production planning | Stock management | Transport integration | Unification of packaging | Optimization of material flows |
|---------------------------------|------------------------------------|---------------------|------------------|-----------------------|--------------------------|--------------------------------|
| A | 1,35% | 0,24% | 0,61% | 0,25% | 0,03% | 0,44% |
| B | 0,92% | 0,10% | 0,57% | 0,05% | 0,02% | 0,18% |
| C | -0,57% | 0,04% | 0,33% | -0,07% | -0,02% | -0,24% |
| D | -1,70% | -0,38% | -1,51% | -0,23% | -0,03% | -0,38% |
| Mean absolute difference | 1,14% | 0,19% | 0,76% | 0,15% | 0,03% | 0,31% |

Source: own study

Table 4. Values of differences of indicator Service level from its mean value
 Tabela 4. Wartości różnicy miary poziom obsługi klienta od jej wartości średniej

| Integration level | Accessibility of recycled material | Production planning | Stock management | Transport integration | Unification of packaging | Optimization of material flows |
|---------------------------------|------------------------------------|---------------------|------------------|-----------------------|--------------------------|--------------------------------|
| A | 0,94% | 8,41% | 3,97% | 0,04% | 0,08% | 0,42% |
| B | 0,92% | -1,12% | 2,51% | 0,00% | 0,00% | 0,01% |
| C | -0,90% | -1,58% | -1,92% | -0,01% | -0,04% | -0,08% |
| D | -0,96% | -5,71% | -4,56% | -0,03% | -0,04% | -0,35% |
| Mean absolute difference | 0,93% | 4,21% | 3,24% | 0,02% | 0,04% | 0,22% |

Source: own study

The mean absolute difference is given at the bottom of each of tables 2-4. It is a value calculated as an arithmetic mean of absolute differences at each integration level. It indicates how much the indicator, calculated as a mean value, is different at each of integration level comparing to the mean value, but it does not indicate whether this difference is positive or negative.

Ranking of integration factors

The mean absolute values, presented above, were used to prepare the ranking of integration

factors. The ratio of mean absolute value to mean global value of a given indicator was calculated to prepare a standardization of results.

The following mean values of indicators for supply chains were used in above mentioned calculation: cashflow = 2 585 527,86 PLN, profitability = 26,74%, service level = 89,06%. The results for all integration factors are presented in the table 5.

Table 5. The ratio of mean absolute value to mean global value of indicators for supply chains
 Tabela 5. Stosunek średnich różnic bezwzględnych do wartości średnich miar łańcucha dostaw

| Indicator | Accessibility of recycled material | Production planning | Stock management | Transport integration | Unification of packaging | Optimization of material flows |
|---------------|------------------------------------|---------------------|------------------|-----------------------|--------------------------|--------------------------------|
| Cashflow | 1,66% | 7,39% | 20,28% | 0,23% | 0,04% | 1,20% |
| Profitability | 4,24% | 0,71% | 2,82% | 0,56% | 0,09% | 1,16% |
| Service level | 1,04% | 4,72% | 3,64% | 0,02% | 0,04% | 0,24% |

Source: own study

Based on the table 5, the ranking of integration factors were prepared according to the rule: the highest percent ratio of absolute mean difference to global mean value means the highest (1) place in the ranking. The ranking list was presented in the table 6.

The ranking of integration factors was prepared in three perspectives related to separate indicators of the supply chain. The

place in the ranking was not assigned in the situation when the ANOVA analysis shows no statistical significance between differences for the given pair (indicator and factor). There is also a possibility to prepare an alternative version of the ranking of integration factors according to average influence of the factor on three defined indicators of the supply chain. The ranking list prepared in this way is presented in the table 7.

Table 6. The ranking of integration factors
 Tabela 6. Ranking czynników integracji

| Indicator | Accessibility of recycled material | Production planning | Stock management | Transport integration | Unification of packaging | Optimization of material flows |
|---------------|------------------------------------|---------------------|------------------|-----------------------|--------------------------|--------------------------------|
| Cashflow | 3 | 2 | 1 | - | - | 4 |
| Profitability | 1 | 4 | 2 | 5 | - | 3 |
| Service level | 3 | 1 | 2 | - | - | 4 |

Source: own study

Table 7. Average influence of integration factors on the indicators of supply chains
 Tabela 7. Średni wpływ czynników integracji na miary łańcucha dostaw

| Indicator | Accessibility of recycled material | Production planning | Stock management | Transport integration | Unification of packaging | Optimization of material flows |
|-------------------|------------------------------------|---------------------|------------------|-----------------------|--------------------------|--------------------------------|
| Cashflow | 1,66% | 7,39% | 20,28% | 0,23% | 0,04% | 1,20% |
| Profitability | 4,24% | 0,71% | 2,82% | 0,56% | 0,09% | 1,16% |
| Service level | 1,04% | 4,72% | 3,64% | 0,02% | 0,04% | 0,24% |
| average influence | 2,32% | 4,27% | 8,91% | 0,27% | 0,06% | 0,87% |
| ranking position | 3 | 2 | 1 | - | - | 4 |

Source: own study

The place in the ranking was not assigned in the situation when the influence was not statistically significant, similarly as in the first version of the ranking. The advantage of this version is the precise determination of the position in the ranking. However it is obtained by the lost of transparency of the perspective of the evaluation in relation to each of the indicator separately.

CONCLUSIONS

Resuming the results of the hierarchization of integration factors in supply chains of forward and backward type, it can be noted the creation of the following triad: stock

management, production planning and accessibility of recycled materials. These characteristics and in this sequence build the first basic line of integration factors in supply chains. The less important integration factor is only the optimization of material flows. Other factors (transport management and unification of packages) have no statistically significant influence on the results of the supply chain. These results confirm still actual significance of factors of stock management and production planning - more typical for on-way supply chains and the factor of accessibility of recycled material - typical for two-way supply chains. The final results of the researches enter into the transformation of the supply chain into the eco-chain.

Authors made the identification and selection of integration factors in two-way supply chains. The next step was the evaluation of each factor regarding the strength (value of the indicator) and direction (sign of the indicator) of the interaction. Knowing these relationships, it is possible to create fruitful cooperation within supply chains in rational and conscious way. Very complicated conditions of functioning are typical for the area of researches, chosen by authors. They are not directly susceptible on the transfer of standard solutions. Despite of that, authors took the challenge to explain the influence of integration factors on the results of supply chains in a quantitative way. The previous researches, known to authors, in this area were only of qualitative nature (integration models). Authors hope that obtained results will be useful for other researchers and managers, operating in areas connecting with supply chains as well as they will inspire to further researches in this area.

ACKNOWLEDGEMENT

This paper has been the result of the study conducted within the grant by the National Science Centre, entitled "Investigating multi-aspect determinants of integration in backward and forward logistics chains in respect of integrated production planning in the context of using recyclable materials" (project No. UMO-2011/03/B/HS4/03419) pursued at the Poznań School of Logistics in Poznań.

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RANKING CZYNNIKÓW INTEGRACJI W ŁAŃCUCHACH LOGISTYCZNYCH TYPU FORWARD I BACKWARD – REKOMENDACJE Z BADAŃ

STRESZCZENIE. Wstęp: Trendy integracyjne są jedną z głównych determinant rozwoju współczesnej logistyki. Obecnie po fazie zainteresowania łańcuchami dostaw realizującymi jedynie przepływy jednokierunkowe, nadeszła era łańcuchów dwukierunkowych typu forward i backward, realizujących jednocześnie przepływy w przód i w tył. Możliwość różnorodnej konfiguracji ogniw w takich łańcuchach dostaw wymaga zidentyfikowania czynników integracji oraz ustalenia ich stopnia oddziaływania na wyniki łańcucha dostaw. Doświadczenia nauki i praktyki łańcuchów dostaw zwracają uwagę na pilną potrzebę poznania uwarunkowań integracji w łańcuchach działających dwukierunkowo.

Metody: Prace związane z modelowaniem i realizacją eksperymentów symulacyjnych zjawiska integracji w łańcuchach logistycznych typu forward i backward przeprowadzono w środowisku iGrafx Process 2013 for Six Sigma. Uzyskany w ich trakcie materiał empiryczny poddano następnie obróbce statystycznej w pakiecie Minitab 17. Identyfikacja istotności różnic wyników została dokonana w oparciu o analizę wariancji ANOVA. Dopełnieniem analizy wariancji jest analiza wartości różnic w postaci średnich bezwzględnych. Podstawę oceny integracji łańcucha dostaw typu forward i backward stanowią następujące miary: cashflow, rentowność i poziom obsługi klienta.

Wyniki: Przeprowadzono 8 192 eksperymenty symulacyjne dla 6 czynników integracji: dostępność surowca wtórnego, planowanie produkcji, zarządzanie zapasami, integracja działań transportowych, unifikacja opakowań i optymalizacja przepływu materiałowego. W oparciu o wyniki analiz istotności i wartości różnic otrzymano wyniki wpływu danego czynnika integracji na wyniki globalne łańcucha dostaw typu forward i backward. Posłużyły one do stworzenia rankingu czynników integracji. Głównymi czynnikami kształtującymi postać integracji łańcuchów dwukierunkowych są w kolejności: zarządzanie zapasami, planowanie produkcji oraz dostępność surowców wtórnych.

Wnioski: Integracja oferuje nowe możliwości stąd jest to obiecująca opcja działania. W skomplikowanych i złożonych realiach logistycznych coraz trudniej ekonomicznie funkcjonować bez podejmowania form bliższej współpracy i zacieśniania tych więzi, czasami jest to wręcz niemożliwe. Rosnąca popularność łańcuchów dwukierunkowych otwiera nowe wymiary możliwości współpracy. Jednak nauce i praktyce potrzeba wiarygodnych informacji ilościowych na temat świadomego kreowania zjawiska integracji w łańcuchach logistycznych. Takie narzędzie może stanowić rekomendowana w artykule lista (ranking) czynników integracji w perspektywie trzech miar oceny globalnego stopnia funkcjonowania łańcucha dostaw.

Słowa kluczowe: ranking czynników integracji, modelowanie i symulacja łańcucha dostaw, miary łańcucha dostaw.

RANKING VON INTEGRATIONSFAKTOREN IN DEN LIEFERKETTEN VOM TYP FORWARD UND BACKWARD - DIE FORSCHUNGSGESTÜTZTEN EMPFEHLUNGEN

ZUSAMMENFASSUNG. Einleitung: Die Integrationstrends stellen heutzutage einen der wesentlichsten Einflussfaktoren der modernen Logistik dar. Nach einer Phase, in welcher das Interesse an den auf die nur in eine Richtung strömenden Materialflüsse orientierten Lieferketten bestand, kam die Zeit für die Zwei-Richtungen-Lieferketten vom Typ forward und backward, die die Materialflüsse vorwärts- und rückwärtssteuern können. Die Möglichkeit unterschiedlicher Konfiguration der Glieder innerhalb solcher Ketten bedarf einer Identifizierung von Integrationsfaktoren und Festlegung deren Beeinflussung von Ergebnissen der Lieferkette. Die Erfahrungen aus Forschung und Praxis bezüglich der Lieferketten weisen auf die akute Notwendigkeit der Ermittlung von Voraussetzungen für die Integration innerhalb der in zwei Richtungen wirkenden Lieferketten hin.

Methoden: Die Forschungsarbeiten, die mit Modellierung und Ausführung von Simulationsexperimenten in Bezug auf Integrationserscheinungen innerhalb der Lieferketten vom Typ forward und backward verbunden waren, wurden im Medium iGrafx Process 2013 for Six Sigma durchgeführt. Das dadurch gewonnene empirische Material wurde ferner einer statistischen Bearbeitung im Paket Minitab 17 unterzogen. Die Identifizierung der Relevanz von Ergebnisdifferenzen kam mithilfe der Varianz-Analyse ANOVA zustande. Die Vervollkommnung der Varianz-Analyse wird durch die Analyse von Differenzen-Werten in Form von absoluten Mittelwerten erreicht. Als Grundlagen für die Bewertung der Integration der Lieferkette vom Typ forward und backward bestehen folgende Maßstäbe: cashflow, Renatabilität und Niveau des Kundenservices.

Ergebnisse: Es wurden 8192 Simulationsexperimente für 6 Integrationsfaktoren, d.h.: Verfügbarkeit von Sekundärstoffen, Produktionsplanung, Lagerbestandsführung, Integration von Transportaktivitäten, Vereinheitlichung von Verpackungen und Optimierung des Materialflusses, durchgeführt. Gestützt auf die Ergebnisse der Analyse der Relevanz und der Differenzen-Werte ermittelte man den Wert des Einflusses eines Integrationsfaktors auf das Gesamtergebnis der Lieferkette vom Typ forward und backward. Als solche wurden sie für die Aufstellung eines Rankings der betreffenden Integrationsfaktoren in Anspruch genommen. Demzufolge sind: Lagerbestandsführung, Produktionsplanung und Verfügbarkeit von Sekundärstoffen die wichtigsten Faktoren, die die Integration der Zwei-Richtungen-Lieferketten ausgestalten.

Fazit: Die Integration bietet neue Möglichkeiten und daher stellt sie eine vielversprechende Wirkungsoption dar. In der komplizierten und komplexen, logistischen Wirklichkeit fällt es immer schwieriger, ohne Inanspruchnahme der Formen einer engeren Zusammenarbeit und kooperativer Anbindungen wirtschaftlich zu handeln, manchmal ist dies gar nicht möglich. Die wachsende Popularität der Zwei-Richtungen-Lieferketten eröffnet neue Räume für die effektive Betätigung einer Zusammenarbeit in diesem Bereich. Die Wissenschaft und die Praxis bedürfen jedoch glaubwürdiger quantitativer Daten hinsichtlich der bewussten Ausgestaltung der Erscheinung der Integration innerhalb der Logistikketten. Als solch ein Tool dazu kann die im vorliegenden Beitrag empfohlene Auflistung (Ranking) der Integrationsfaktoren in Form von den 3 Maßstäben für die Bewertung des Gesamt-Wirkungsgrades bei Funktionsausübung einer Lieferkette angesehen werden.

Codewörter: Ranking von Integrationsfaktoren, Modellierung und Simulation der Lieferkette, Maßstäbe der Lieferkette.

Bernd Hentschel
BERLINOXX Projektzentrum Logistiknetzwerke
Prieroser Dorfaue 10
15754 Heidese, OT Prieros, **Germany**
e-mail: info@berlinox.com

Roman Domański
e-mail: roman.domanski@wsl.com.pl
Michał Adamczak
e-mail: michal.adamczak@wsl.com.pl
Piotr Cyplik
e-mail: piotr.cyplik@wsl.com.pl
Łukasz Hadaś
e-mail: lukas.hadas@wsl.com.pl
Martyna Kupczyk
e-mail: martyna.kupczyk@wsl.com.pl
Żaneta Pruska
e-mail: zaneta.pruska@wsl.com.pl

Poznan School of Logistics
Estkowskiego 6, 61-755 Poznan, **Poland**
