MANAGING RISKS IN LOGISTICS USING FMEA-DEA APPROACH

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Abstract: Modern logistics markets, characterized by complex structure and tough competition, are all exposed to various risks. These can cause different problems and disturbances. In recent years, increasing attention has been paid to managing risks in logistics. There are different systematizations of risks, as well as methods used for risk identification, analysis and evaluation. One of the most important and most frequently used methods is Failure Mode and Effects Analysis (FMEA) approach. Due to its simple application and usable results, the FMEA method has been widely used. However, this method also has some disadvantages. One of the most frequently mentioned in the literature is the calculation of Risk Priority Number (RPN). In this paper, for improving the RPN calculation for risks in different logistics processes, Data Envelopment Analysis (DEA) approach is proposed. The approach has been tested in two real examples. The first relates to 58 logistics risks in international commodity flows, while the second concerns risks for 37 activities in product distribution. In the first example, the most important risks are identified as congestion (border, customs offices, incomplete documentation, wrong addresses (loading/unloading), etc.) In the distribution process, the risks with dominant priority are delay in transportation process, goods control (low quality, short expiration date) and order-picking process (goods extraction and putting on pallets). According to the results, the proposed approach has great applicability for managing risks in logistics.

Keywords: Risks management, Logistics, Failure Mode and Effects Analysis, Data Envelopment Analysis

1. INTRODUCTION

Recently, risk management has been the focus of academics and practitioners. There are different definitions of risks in the literature. Risk, in general, is defined as “the probability of variance in an expected outcome” or “the chance, in quantitative terms, of a defined hazard occurring” (Spekman and Davis, 2004). The risks are investigated in different areas and there are differences between term definition and observed aspects across different sectors.

In logistics, risks are related to negative consequences, such as danger, damage, injury, or any other undesired consequences (Harland et al., 2003). Supply chain risk is often specified into operational risks and disruption risks, built upon the characteristics of the risks (Tang 2006). In this sense, operational risks refer to inherent uncertainties from
supply, demand and cost, whose frequency is high while impact is low. On the contrary, disruption risks indicate major natural and man-made disasters whose impact is much greater than operational risks, though the likelihood is slim (Kwak, 2014).

Different approaches are used for risk management in logistics (Kwak, 2014). One of the most frequently used approaches generally, but also in logistics, is Failure Mode and Effects Analysis (FMEA). In this paper, the possibilities of improving the application of the traditional FMEA approach in logistics have been explored. A special emphasis is given to the Data Envelopment Analysis (DEA) approach. The aim of the paper is to develop an efficient risk management tool for logistics processes available in different systems and at different levels. The proposed approach takes into account relative importance weights of risk factors, yet without subjectivity.

The paper is organized as follows. The next section provides the description of risks in logistics, as well as a review of different approaches for risks management in logistics. The proposed FMEA-DEA approach for risks management in logistics is presented in third section. In fourth section, the proposed approach is tested on two numerical examples. At the end of the paper, concluding remarks and directions for future research are specified.

2. PROBLEM DESCRIPTION

In this chapter, main risks in logistics are explored. Furthermore, approaches for risk management are investigated and shortly described.

2.1 Risks in logistics

As already mentioned, generally, risk management in recent years has gained significance. The same situation is in logistics. Logistics is crucial for linking upstream and downstream parties. In this sense, any logistics disruption can cause a number of negative consequences. At the end, everything is projected to the customer and their dissatisfaction. Regardless the size and structure of the logistics system, the risks can be divided into internal and external, or exogenous and endogenous (Trkman and McCormack, 2009). More complex logistics systems and processes have the higher likelihood of risk occurrence.

It is very important to emphasize that a disruption in a process or a system will affect performances of the entire system or chain. All activities and processes need to be planned in advance. Risk management should be an important part of the enterprise risk management. When an unwanted event occurs, it is very important to solve the problem successfully, quickly, and with fewer consequences. For this reason, flexible and adaptive logistics is very important.

In accordance with a point of event occurrence, risk management strategy can be divided into two approaches: mitigation strategy and contingency strategy. Mitigation strategy represents pre-actions to avoid or minimize the likelihood of a risk attacking or its impact. Contingency strategy refers to post-actions to handle damage in a quick and short time with minimal expense (Wee and Blos, 2012). Mitigation action is used for managing the risk sources and contingency action for handling the risk consequences.
As mentioned before, mitigation strategy is a set of planning activities before the event happened. Mitigation strategy should prepare the system or process for a specific disturbance or threat. In addition, certain costs will be incurred in order to avoid the disruption or lower the losses. Chopra and Sodhi (2004) defined the threats in the supply chains, seven mitigation approaches and their tailored strategies. Tang (2006) identified robust strategies for mitigating supply chain disruptions. Pettit et al. (2010) identified a zone of resilience defined by the supply chain capability and vulnerability. Contingency strategy is aiming to rapidly respond to the disruption event and also to recover quickly from that event with minimum expenses (Wee and Blos, 2012). Mitigation strategy and contingency strategy are highly interconnected. Mitigation strategy should reduce likelihood of risk occurrence and lower the costs of contingency actions.

There are five risk categories in an enterprise; these include strategic, financial, operational, human capital, and hazard categories to assess and manage risks. According to Wee and Blos (2012), all logistics risks relate to physical and information flow, as shown in Figure 1.

![Figure 1. Risk management in logistics (Wee and Blos, 2012)](image-url)

The basic processes for risk management in logistics are risk identification, evaluation, mitigation, implementation, and monitoring. Logistics management functions are largely affected by certain risks. In that manner, each sector will focus on, for them, the most important risks (Table 1).

In the literature, there are different risks in logistics systems. According to Kwak (2014), the most important risks in intercontinental commodity flows are delay, natural disasters, space shortage, freight rate fluctuation, miscommunication, cargo damage, inaccurate documents, strike, etc. In recent years, one of the most important categories
in logistics is the risk of poor quality. Bearing that in mind, there is a need for the continuous monitoring of potential risks, as well as measuring the quality level of the delivered services (Kilibarda et al. 2016).

Table 1: Risks in different logistics management functions (Wee and Blos, 2012)

| Risks/Functions          | Transportation management | Warehousing management | Material handling | Inventory management | Order management | Purchasing management | Customer service | Information management |
|--------------------------|---------------------------|------------------------|-------------------|---------------------|-----------------|-----------------------|------------------|------------------------|
| Environment              | *                         | *                      | *                 | *                   |                 |                       | *                | *                      |
| Suppliers                |                           |                        |                   |                     |                 |                       |                  |                        |
| Operational              | *                         | *                      |                   | *                   | *               |                       | *                | *                      |
| Control                  | *                         |                        |                   |                     |                 |                       |                  |                        |
| Planning                 |                           |                        |                   |                     | *               |                       | *                | *                      |
| Customers                |                           |                        |                   |                     |                 |                       |                  |                        |
| Information              | *                         | *                      |                   | *                   | *               |                       | *                | *                      |

2.2 Different approaches for risk management in logistics

For managing risks there is a number of approaches, classified in different ways. According to Wee and Blos (2012), there are different techniques for different stages of risks management (Table 2).

Table 2. Assessment techniques in different stages (adapted: Wee and Blos, 2012)

| Stage         | Assessment techniques                                                                 |
|---------------|---------------------------------------------------------------------------------------|
| Identification| Brainstorming, Structure or Semi-Structure Interview, Delphi, Check-list, Primary hazard analysis, HAZOP, HACCP, Environment risk assessment, Structure-What if-SWIFT, Scenario analysis, FMEA, Cause-and-effect analysis, Human reliability analysis, Reliability-centered maintenance, Consequence/probability matrix, Multiple FMEA, MCGDM |
| Analysis      | HAZOP, HACCP, Environment risk assessment, Structure-What if-SWIFT, Scenario analysis, Business impact analysis, Root cause analysis, FMEA, Fault tree analysis, Event tree analysis, Cause and consequence analysis, Cause-and-effect analysis, LOPA, Decision tree, Human reliability analysis, Bow tie analysis, Reliability-centered maintenance, Markov analysis, Bayesian statistics and Bayes Nets, FN curves, Risk indices, Consequence/probability matrix, Cost/Benefit analysis, Multi-criteria decision analysis, FMEA-DEA, FMECA, KANO-FMEA |
| Evaluation    | HACCP, Environment risk assessment, Structure-What if-SWIFT, Root cause analysis, FMEA, Reliability-centered maintenance, Monte Carlo simulation, Bayesian statistics and Bayes Nets, FN curves, Risk indices, QFD - FMEA |
There is also ASSE (American Society of Safety Engineers) classification into Qualitative methodology (Preliminary risk analysis, HAZOP, FMEA), Tree-based technology (Failure tree analysis, Event tree analysis, Cause - Consequences analysis, Management oversight risk tree, Safety management organization review technique), and Techniques for dynamic system (Go method, Diagraph/Fault graph, Markov modeling, Dynamic event logic analytic methodology, Dynamic event tree analysis method).

One of the most important and most frequently used engineering technique methods is FMEA. FMEA is a decision-making tool for defining, identifying and eliminating potential failures, problems and errors from the system, design, process, or service before they reach the customer. In literature, FMEA is combined with different approaches and methods. In order to determine risk priority number, some authors used DEA. FMEA-DEA also provides corrective information regarding the failure factors – severity, occurrence and detection (Chin et al. 2009; Chang and Sun, 2009).

The Fault Tree Analysis is mainly applied as an addition to the FMEA to enhance the analysis or to replace the FMEA completely in order to cover the failure combination possibilities (Pickard et al. 2005). The proposed procedure allows considering multiple failures while keeping all elements of FMEA (Xiao et al. 2011). FMEA is also extended with Criticality Analysis (CA). In that manner, Failure Modes, Effects and Criticality Analysis (FMECA) may also rank each failure according to the criticality of a failure effect and its probability of occurrence. Some benefits of FMECA approach are the following: contribution to the improved designs for products and processes (greater reliability, better quality, enlarged safety); improvement in consumer satisfaction (contributes to cost savings, decreases development time, warranty costs, waste, etc.); and contribution to the development of control plans, testing requirements, optimum maintenance plans, reliability growth analysis and related activities (Lipol and Haq, 2011).

The risk priorities of failure modes are almost crisp, which has been criticized due to several limitations. Some authors used multi-criteria group decision making (MCGDM) approach in order to use linguistic variables and to obtain better solution. Nazam et al. (2015) applied fuzzy technique for order performance by similarity to ideal solution (TOPSIS) integrated with fuzzy analytical hierarchy process (AHP) in the food retail chain.

FMEA is also integrated with Kano model. Shahin (2004) combined FMEA and Kano in order to enhance FMEA capabilities through its integration with Kano model. The main reason is that the severity is being determined from the designers’ point of view, not from the customers’ side. It supports the nonlinear relationship between frequency and severity of failure. Likewise, a new index called “correction ratio” (Cr) is proposed to assess the corrective actions in FMEA (Shahin, 2004).

Almannai et al. (2008) used quality function deployment (QFD) technique and the failure mode and effects analysis (FMEA) technique. The main reason for this combination is the ability of QFD to identify the most suitable alternative and the ability of FMEA to identify the associated risk.
3. FMEA-DEA APPROACH

In this chapter, FMEA-DEA approach for risk management in logistics is described in more details. The advantages of applying this approach are also highlighted.

**Failure Mode and Effects Analysis (FMEA) Approach**

As mentioned before, FMEA was developed for the failure analysis in different systems and processes. The procedure of this method is based on the failure characteristics and structure of observed systems and processes. The main objective of FMEA is to analyze potential defects/faults in the observed system and corrective measures that can reduce the risks. Benefits of failure detection are numerous: increasing the safety of functions and service reliability, reducing warranty and service costs, shortening the development process, obtaining better compliance of the planned terms, increasing process efficiency, increasing customer satisfaction, etc. FMEA discovers and prioritizes failures by computing the risk priority number (RPN) which is a product of several risk factors: severity (S), occurrence (O) and detection (D) (Andrejić and Kilibarda, 2017).

Severity describes the seriousness (effects) of the failure. Each effect is given a severity number from 1 (no danger) to 10 (critical). In this paper, severity ratings proposed in (Chin et al., 2009b) are used (Table 3). Occurrence describes the probability of failure appearance. Traditional ratings for failure occurrence proposed in (Chin et al., 2009) are used in this paper (Table 3). The ability to detect the failure before it reaches the customers can be defined as detection. The assigned detection number measures the risk that the failure will escape detection. A high detection number indicates that the chances are high that the failure will escape detection, or in other words, that the chances of detection are low (Andrejić and Kilibarda, 2017). Detection ratings used in this paper are presented in Table 3.

| Rating | Severity - S                     | Probability of occurrence- O                        | Detection - D            |
|--------|----------------------------------|----------------------------------------------------|--------------------------|
| 10     | Hazardous without warning        | Very high: failure is almost inevitable             | Absolute uncertainty     |
| 9      | Hazardous with warning           | Very remote                                        |                          |
| 8      | Very high                        | High: repeated failures                             | Remote                   |
| 7      | High                             | Very low                                           |                          |
| 6      | Moderate                         | Moderate: occasional failures                       | Low                      |
| 5      | Low                              | Moderate                                           |                          |
| 4      | Very low                         | Moderate high                                      |                          |
| 3      | Minor                            | Low: relatively few failures                        | High                     |
| 2      | Very minor                       | Very high                                          |                          |
| 1      | None                             | Remote: failure is unlikely                         | Almost certain           |

RPN is calculated after the determination of three mentioned components. The RPN can be easily calculated by multiplying three mentioned components:

\[
RPN = S \times O \times D
\]  

The failure modes with the highest RPN should have the highest priority for monitoring and corrective actions. The main problem with standard FMEA approaches is the
calculation of RPN. As mentioned before, according to a traditional approach, RPN is calculated as the product of severity, detection and occurrence. However, with DEA approach, a frontier is established considering the less critical failure modes. The mentioned approach also provides useful information about how much each failure mode has to be improved to become relatively acceptable.

**Data Envelopment analysis (DEA)**

DEA is a mathematical programming technique which enables the comparison of efficiencies of different Decision Making Units (DMUs), based on multiple inputs and outputs. The efficiency is relative and relates to the set of units within the analysis. Charnes et al. (1978) proposed a non-parametric approach for efficiency estimation, where they reduce multiple inputs to a single virtual input and multiple outputs were reduced to a single virtual output using weighting coefficients. In the set of homogeneous units, the DEA finds the most efficient DMUs and according to them, it defines the efficiency of other units. This method is also used for obtaining information about corrective actions of inefficient DMUs. Obtained efficiencies are relative since they relate only to a set of observed DMUs and they cannot be considered as absolute (Andrejic et al., 2013).

The basic CCR (Charnes, Cooper, Rhodes, 1978) model presents the basis of all present models. In the original form, this model presents the problem of fractional programming. According to the appropriate transformations, the model is reduced to the linear programming problem. In order to estimate DMU efficiency, it is necessary to have data of consumed input and realized output variables. The following notation is most frequently used in the DEA terminology. A set of DMUs has \( n \) DMU \((j=1, 2, \ldots, n)\), where each input is characterized by \( m \) input \((i=1, 2, \ldots, m)\) and \( s \) output variables \((r=1, 2, \ldots, s)\). The value of \( i \) input variable is denoted as \( x_{ij} \) while \( y_{rj} \) denotes the value of \( r \) output variables of DMU \( j \). Weighting coefficients are related to all inputs and outputs and they are denoted with \( \upsilon_i \) and \( u_r \) respectively. They present decision variables. In order to estimate DMU efficiency of the observed set, it is necessary to perform \( n \) independent estimations where DMU \( k \) \((k=1, \ldots, n)\) presents the failure/risk whose efficiency is measured. In that case, the primal CCR (multiplier form) model has the following form: \( \mu \)

\[
\begin{align*}
\text{Max} & \sum_{r=1}^{s} u_r y_{rk} \\
\sum_{i=1}^{m} v_i x_{ik} &= 1 \\
\sum_{r=1}^{s} \mu_r y_{o} - \sum_{i=1}^{m} v_i x_{ij} &\leq 0, j=1,2,\ldots,n \\
v_i &\geq 0, i=1,\ldots,m \\
u_r &\geq 0, r=1,\ldots,s
\end{align*}
\]

In the process of DEA method application, the CCR model is preferable as the initial model. As in linear programming problems, the CCR model also has two formulations: primal and dual. Dual formulation (envelopment form) of the original CCR model was
used in this paper. There are several benefits of solving the dual problem. Considering
the fact that the number of DMUs is higher than the number of inputs and outputs, in
practice, due to a computational effort, the dual model is mostly solved. Max-slack
solution cannot be obtained by solving the primal model. The interpretation of the dual
model is more straightforward because the solutions are characterized as inputs and
outputs that correspond to the original data, whereas the multipliers provided by
solutions to the primal model represent evaluations of these observed values. CCR dual
model is usually solved in two stages:

Stage I

\[ \text{Min } \theta \] (7)

Subject to:

\[ \sum_{j=1}^{n} \lambda_j y_{rj} - y_{rk} \geq 0, \; r = 1,2,...,s \] (8)

\[ \theta x_{ik} - \sum_{j=1}^{n} \lambda_j x_{ij} \geq 0, \; i = 1,2,...,m \] (9)

\[ \lambda_j \geq 0, \; j = 1,2,...,n \] (10)

Stage II

\[ \text{Max } e \left( \sum_{r=1}^{s} s_r^+ + \sum_{i=1}^{m} s_i^- \right) \] (11)

Subject to:

\[ \sum_{j=1}^{n} \lambda_j y_{rj} - y_{rk} - s_r^+ = 0, r = 1,2,...,s \] (12)

\[ \theta^* x_{ik} - \sum_{j=1}^{n} \lambda_j x_{ij} - s_i^- = 0, i = 1,2,...,m \] (13)

\[ \lambda_j, s_r^+, s_i^- \geq 0, \; i = 1,2,...,m, r = 1,2,...,s, \; j = 1,2,...,n \] (14)

The main problem with standard FMEA approaches is the calculation of RPN. As
mentioned before, according to a traditional approach, RPN is calculated as a product
of severity, detection and occurrence. However, with DEA approach, a frontier is
established considering the less critical failure modes. The mentioned approach also
provides useful information.

The variable \( \theta \) is called the intensity factor, and it shows how it is possible for DMU\( k \) to
proportionally reduce all output variables. The optimal value \( \theta \) is obtained in the first
phase, after which it is used for estimating the efficiency in the second phase. Variables
\( s_r^+ \) and \( s_i^- \) show how it is possible that DMU\( k \) individually reduces \( i \) input variable and
increases \( r \) output variable in order to become efficient. These values are called slack
variables. If from the set of dual weighting coefficients \( \lambda_j \) \( (j = 1, 2, \ldots, n) \) only \( \lambda_k \) has a
positive value, then the intensity factor is $\theta = 1$, which means that DMU$^k$ engaged the minimum amount of input variables and it is the marginal point. If that is not the case, DMU$^k$ is inefficient. DMUs with a positive value for the dual weighting coefficients $\lambda_j$ are called peers for DMU$^k$. Therefore, if $\theta < 1$, then DMU$^k$ is relatively inefficient and it should proportionally reduce all input variables for $(1 - \theta) \times 100$ percentage in order to become efficient with the existing level of output variables.

In order to use FMEA and DEA, it is important to define inputs and outputs. According to DEA characteristics, it is deemed a good alternative tool to enhance the assessment capability of FMEA. The common features of DEA and FMEA are (Chin et al. 2009):

- Determination of risk ranking for failure modes in FMEA as to efficiency ranking of DMUs in DEA;
- Both deem to have inputs and outputs (in FMEA the inputs are severity, occurrence and detection and the output is RPN).

RPNs are presented as relatively risky among failure modes. Prioritized corrective actions are tackled based on the RPN derived from the inputs. The failure modes used in FMEA are equivalent to DMUs in DEA; the inputs (severity, occurrence, detection) of FMEA can be identically seen as multiple inputs of DEA (Chin et al. 2009). The application of DEA in FMEA achieves a number of benefits: risk rankings among failure modes are in terms of cardinal order; information about corrective actions for risk elements (severity, occurrence, detection) are available; resource allocations management is improved, etc.

4. NUMERICAL EXAMPLES

In this section, the proposed model is tested on two different examples. The first example relates to risks in organization of international commodity flow, while the second example investigates risks in distribution processes.

4.1 Applying FMEA-DEA approach for risks analysis in international commodity flows

The importance of global logistics in international trade flows is recognized. In the network of processes and participants, there are numerous risks for logistics providers. Potential risks can greatly disrupt flows and make a number of problems for all participants. The organization of international commodity flows is a complex and often uncertain process (Kilibarda et al., 2016). The freight forwarders and logistics providers as architects of international goods flows have to design, organize and realize all processes and activities. The structure of activities is shown in Figure 2. The first is the purchasing contract between the seller (exporter) and the buyer (importer). The exporter or importer, as users of logistics services, gives a request to freight forwarding companies. After that, they present an appropriate logistic offer. The result of the offer acceptance is a contract for freight forwarding which starts the process of organizing and realizing the international trade flow. Preparation, packaging and loading of goods is the first step. Freight forwarder and customs officer are involved in issuing the export clearance. Documentation preparation (CMR, EUR1, invoice, customs declaration, insurance policy, etc.) and exchange are very important. The next process in the
organization of international flows is transport. Import clearance, unloading, cost calculation, and payment are realized at the end of the international commodity flow.

For the analyzed system, seven processes with 58 potential failures (risks) are identified (Andrejić and Kilibarda, 2018). In order to improve the calculation of the RPN number and gain a more reliable result, FMEA-DEA approach is applied. As inputs in this model O, S, and D are used, while 1 is the artificial output for all DMUs. The O, S, D values are results of the assessment of experts with years of experience in the organization of international commodity flows. Results are presented in Table 4. Unlike the traditional RPN number, in this case, the efficiency scores are calculated. In FMEA-DEA approach, larger efficiency scores refer to less RPN, while less efficiency scores mean larger RPN. In this paper, CCR DEA input-oriented model is used.
Table 4. Analysis of risks in international commodity flows

| Process and loading of goods | Failure | Consequence | O | S | D | FMEA-DEA scores |
|-----------------------------|---------|-------------|---|---|---|-----------------|
| Delay due to retention on previous loading | Delay in delivery (out of term); Problems in customs procedures | 8 | 4 | 8 | 0.84 |
| Wrong loading address (official and real addresses are different) | Empty driving - deadhead (unexpected costs); Time losses (delay - penalties) | 9 | 8 | 9 | 0.64 |
| Inappropriate handling equipment | Manual loading; Engagement of third parties; time losses-delay with delivery | 7 | 7 | 7 | 0.80 |
| Overload (the weight of the shipment exceeds the maximum load) | Problems with law | 5 | 9 | 4 | 1.00 |
| Congestion on loading area | Time losses; Delay in delivery (out of term) | 7 | 7 | 8 | 1.00 |
| Lack of reference / loading number | Problems with loading (inability) | 5 | 4 | 7 | 1.00 |
| Inadequate manipulation of goods while loading | Damage to goods and unexpected costs | 6 | 8 | 8 | 0.75 |
| Loading the wrong goods to the vehicle (returning the vehicle to the place of loading) | Empty driving - deadhead (unexpected costs) | 6 | 6 | 8 | 0.75 |
| Time losses; Delays | | 5 | 8 | 8 | 0.86 |
| Driver takes incomplete (unchecked) documentation | Return to the place of loading due to the lack of documentation (empty drive and unexpected costs) | 8 | 7 | 8 | 0.72 |
| Lack of information - exact place of customs clearance | Additional km unexpected costs | 7 | 9 | 8 | 0.80 |
| The customs procedure longer than 24 hours | Additional costs of engaging the vehicle | 7 | 8 | 8 | 0.63 |
| The supplier has not provided a service-the task assigned to the carrier; poor communication | Delay of delivery | 7 | 8 | 8 | 0.63 |
| Non-working day | Waiting for the first working day - additional costs of engaging the vehicle | 4 | 8 | 5 | 1.00 |
| Documents authentication – forwarder error | Inability to leave the country; Time losses | 6 | 8 | 9 | 0.73 |
Table 4. Analysis of risks in international commodity flows (continued)

| Process                      | Failure                                                                 | Consequence                                                                 | O | S | D | FMEA-DEA scores |
|------------------------------|-------------------------------------------------------------------------|------------------------------------------------------------------------------|---|---|---|------------------|
| Transport                    | The freight forwarder does not prepare and does not send EUR 1 - regardless receiving the announcement | The importer is not exempt from paying import duties                          | 6 | 7 | 7 | 0.83             |
|                              |                                                                         | Import clearance is delayed - waiting for EUR 1; Additional costs of engaging the vehicle | 6 | 8 | 7 | 0.80             |
|                              | Poor communication seller-freight forwarder-importer                   | Delay of delivery                                                            | 8 | 8 | 10| **0.72**         |
|                              |                                                                         | Additional costs of engaging the vehicle                                       | 8 | 8 | 10| **0.72**         |
|                              | Vehicle malfunction                                                     | Delay in delivery (out of term); penalties                                   | 6 | 9 | 9 | 0.73             |
|                              | Traffic congestion                                                      |                                                                               | 9 | 9 | 9 | **0.62**         |
|                              | Construction zone                                                       |                                                                               | 7 | 6 | 6 | 0.90             |
|                              | Inadequate infrastructure                                               |                                                                               | 6 | 6 | 5 | 1.00             |
|                              | Bad weather conditions                                                  |                                                                               | 6 | 8 | 6 | 0.85             |
| Import clearance             | Traffic accident                                                        |                                                                               | 6 | 7 | 10| 0.77             |
|                              | Congestion at the border                                                |                                                                               | 8 | 9 | 9 | **0.64**         |
|                              | Theft of goods                                                          | Unwanted costs and losses                                                    | 6 | 8 | 6 | 0.85             |
| Unloading                    | Poor security of goods in transport                                     | Unwanted costs and losses                                                    | 7 | 8 | 7 | 0.76             |
|                              | Damaged goods in transport                                              | Damaged goods and unwanted costs                                             | 7 | 7 | 8 | 0.75             |
|                              | Inappropriate temperature                                               | Damaged goods and unwanted costs                                             | 7 | 8 | 8 | **0.72**         |
|                              | Improper packaging; non palletized goods                                | Damaged goods and unwanted costs                                             | 7 | 8 | 8 | **0.72**         |
|                              | Delayed arrivals                                                        | Delay in delivery (out of term)                                              | 8 | 8 | 7 | **0.74**         |
|                              | Congestion in customs offices                                           | Delay in delivery (out of term)                                              | 9 | 9 | 8 | **0.65**         |
|                              | Freight forwarder failure in declaration filling                        | Vehicle retention at the customs office, delay in delivery                   | 6 | 8 | 7 | 0.80             |
|                              | The importer is not able to pay the customs duties; vehicle is captured | Additional costs of engaging the vehicle                                      | 6 | 3 | 7 | 1.00             |
|                              | Customs officer consider subject incomplete                              | Delay in delivery (out of term)                                              | 6 | 3 | 7 | 1.00             |
|                              | Lack of labor in providing freight forwarding services                   | Delay in delivery (out of term)                                              | 6 | 3 | 8 | 1.00             |
|                              | Customs account delays                                                  | Inability to deliver on the same day - delays                                | 7 | 3 | 9 | 1.00             |
| Unloading                    | Wrong unloading address (official and real addresses are different)     | Empty driving - deadhead (unexpected costs)                                  | 9 | 8 | 9 | **0.64**         |
|                              | Vehicle arrival after working time                                      | Time losses (delay - penalties)                                              | 9 | 9 | 9 | **0.62**         |
|                              | Inappropriate handling equipment                                         | Unloading is postponed for the next day; Vehicle retention                   | 8 | 8 | 7 | 0.74             |
|                              | Inadequate manipulation of goods while loading                           | Vehicle retention; Additional costs                                          | 7 | 7 | 6 | 0.85             |
|                              | Congestion on loading area                                              | Damage to goods and unexpected costs                                         | 6 | 8 | 8 | 0.75             |
| Cost calculation and payment | Bad costs calculation and inappropriate offer                            | Income loss                                                                  | 8 | 8 | 7 | 0.74             |
|                              | Bad anticipation of unexpected costs                                     |                                                                                     | 9 | 9 | 7 | **0.70**         |
|                              | Inappropriate customer assessment                                        | Inability to charge                                                          | 7 | 8 | 8 | **0.72**         |
|                              | Inappropriate banking service                                           | Problems in transfer and realization of payments                              | 6 | 7 | 7 | 0.83             |
The first process in the observed case is the preparation and loading of goods. According to the efficiency scores for the observed process, the most important failure is wrong loading address (Table 4). The address of the factory is not the place where the goods are stored. Mentioned failure is the result of poor communication between importers and suppliers, as well as misunderstanding in the business of both parties. This occurrence is high, especially during the first purchase from an unknown supplier. Production warehouse in some cases can be located nearby, so losses are less in such cases. However, it often happens that the warehouse is located hundreds of kilometers away from the address that is entered on the order. Therefore, the truck travels the same distance twice, and thus additional costs are doubled. These errors are rarely detected before the vehicle arrives at the wrong address, especially when the address of the loading is found in the internet databases. Timely error detection can be prevented by contacting the supplier directly. The consequences are also time losses and penalties. There are also risks with medium importance like inadequate manipulation of goods while loading and inappropriate handling equipment. Risks from this group have to be monitored. In the end, there are risks with lowest importance (overload, lack of reference/loading number, etc). Risks in this group do not require special attention.

In the process of documents preparation and exchange, the most important risk is taking incomplete documentation with the score 0.72 (Table 4). The problem usually occurs due to lack of time. This failure can also be caused by previous delays, which are often in practice. The consequences may include returning to the place of loading due to the lack of documentation, empty drive, unexpected costs, etc. In order to overcome the mentioned failure, it is necessary to provide additional instructions to the driver regarding the verification of documents. The driver needs to inform freight forwarder when the document validation is complete. The next risk relates to discrepancies in values and quantities in the invoice, CMR and other documents with the score 0.74. Due to insufficient attention in the process of form filling, inconsistencies in the documents may appear. Consequences include problems in customs procedures.

According to the results in Table 4, the most important risks are related to the customs procedure longer than 24 hours and poor communication between seller-freight and forwarder-importer with the scores 0.63 and 0.72 respectively. Both risks have same consequences in additional costs of engaging the vehicle and delay of delivery. Communication among all participants is essential for the smooth organization of commodity flows. Poor communication causes additional costs, time losses, and in some cases damage and loss of goods, dissatisfaction of all participants, etc. Transporters, freight forwarders, and logistics providers are not able to detect failures that have a direct impact on their operations. The task of a logistics provider is to contact the seller directly with the approval of the importer and try to obtain the necessary information, as well as anticipate and solve the problem that directly threatens a certain trade flow. Regardless the INCOTERMS (International Commercial Terms) rules, in some cases communication between the supplier and freight forwarder is very important.

According to the results, the most important risk in the process of transport is traffic congestion. Congestions on the road are frequent and it is not easy to predict and avoid them (Table 4). In such situation, clients are often dissatisfied and often intolerant due to delays. In some cases, the delay of goods delivery can result in production stopping. The inability to detect or find alternative solutions is the core of this problem.
Congestion on the border has similar consequences as previous failure. This failure is also impossible to anticipate and avoid. The potential solution is the choice of another border crossing. However, the vehicle is often conditioned to cross border in a certain place defined in instructions of the importer. In the case of holidays and non-working days, the congestion is additionally increased. In addition to the above mentioned, there are also the following risks: traffic accident, vehicle malfunction, damaged goods in transport, improper packaging, inappropriate temperature, etc.

In the process of import clearance, the most important failure is congestion in customs offices with the score 0.65. The delays in the arrival of the vehicle to the customs office mean the impossibility of starting the customs clearance procedure, so the clearance procedure is postponed for the following day. Defined terms of delivery cannot be realized in this case. Retention can be on loading, during the road, at the border, as well as in the customs office. The late arrival of the vehicle has a negative impact on all participants. In addition, there are also the following risks: the customs officer considers subject incomplete, lack of labor in providing freight forwarding services, the importer is not able to pay the customs duties, etc.

As mentioned, in the process of loading, the dominant failure by FMEA-DEA approach is wrong loading address (Table 4). The main problem is the fact that it is not easy to detect this failure. The consequences are also time losses and penalties. The next failure in the process of unloading refers to vehicle arrival after working time. The consequences are postponing the unloading for the following day. Other failures (inappropriate handling equipment, inadequate manipulation of goods while loading and congestion on loading area) have less impact. The process of calculating costs and payments is very important and it is necessary to consider it, especially in the initial part. As shown in Table 4, the most common problem is inadequate calculation and anticipation of costs with the score 0.70. The consequence is the loss of revenue. Before contracting, it is necessary to verify and evaluate the client. Problems with inability to charge services can be overcome by inspecting the client. Inappropriate banking services can cause problems in transfer and realization of payments. According to the previous comments, it can be concluded that a large number of risks affects international commodity flows. Risk management is the key to overcoming potential problems. Setting priorities in risk management is one of the main contributions of the proposed approach.

4.2 Applying FME-DEA approach for risks analysis in product distribution

In this part of the paper, the risks in product distribution are analyzed in more details. The proposed approach is applied in order to determine the priorities of risks in a reliable way. Distribution process analyzed in this paper is presented in Figure 3. One of the first processes is the product ordering with two segments: ordering from suppliers and customer ordering. Warehousing is the next process with two groups of activities: activities related to goods receiving and being stored, and activities related to order processing and preparing for delivery. Order picking, as the work intensive process with a large number of potential failures, is the crucial process in warehouses (Andrejić et al, 2013). Packaging process is realized through merging goods from different segments, forming transport units, goods inspection, as well as loading goods in vehicles. The transport is the key process in the product distribution process and largely affects customer satisfaction (Andrejić et al, 2016). Inventory management is the process that is
related to all mentioned processes. At the end is the unloading process in the retail stores.

Figure 3. Distribution process decomposition (Andrejić and Kilibarda, 2017)
In order to gain more reliable results for RPN numbers, in this paper, FMEA-DEA approach is used. Results for all 37 activities are shown in Table 5. As mentioned before, in FMEA-DEA approach larger efficiency scores refer to less RPN, and contrary.

Table 5: Analysis of risks in product distribution

| Process | R | P | N | FMEA-DEA RPN |
|---------|---|---|---|-------------|
| O1      | 6 | 5 | 3 | 0.67        |
| O2      | 5 | 3 | 3 | 0.67        |
| O3      | 4 | 5 | 4 | 0.50        |
| O4      | 6 | 7 | 5 | 0.40        |
| O5      | 4 | 5 | 4 | 0.50        |
| O6      | 2 | 2 | 3 | 1.00        |
| O7      | 6 | 5 | 5 | 0.40        |
| O8      | 5 | 6 | 3 | 0.67        |
| O9      | 7 | 5 | 4 | 0.50        |
| O10     | 4 | 5 | 4 | 0.50        |
| W1      | 2 | 2 | 2 | 1.00        |
| W2      | 8 | 5 | 4 | 0.50        |
| W3      | 5 | 5 | 4 | 0.50        |
| W4      | 7 | 6 | 7 | 0.33        |
| W5      | 4 | 5 | 6 | 0.50        |
| W6      | 5 | 4 | 4 | 0.50        |
| W7      | 3 | 3 | 3 | 0.67        |
| W8      | 8 | 6 | 5 | 0.40        |
| W9      | 6 | 6 | 7 | 0.33        |

| Process | R | P | N | FMEA-DEA RPN |
|---------|---|---|---|-------------|
| W10     | 4 | 3 | 3 | 0.67        |
| F1      | 8 | 5 | 5 | 0.40        |
| P2      | 3 | 4 | 3 | 0.67        |
| P3      | 6 | 5 | 5 | 0.40        |
| P4      | 2 | 3 | 4 | 1.00        |
| I1      | 3 | 4 | 4 | 0.67        |
| I2      | 6 | 6 | 5 | 0.40        |
| I3      | 4 | 3 | 4 | 0.67        |
| I4      | 4 | 4 | 4 | 0.50        |
| I5      | 7 | 6 | 5 | 0.40        |
| I6      | 4 | 5 | 4 | 0.50        |
| T1      | 6 | 5 | 5 | 0.40        |
| T2      | 4 | 3 | 4 | 0.67        |
| T3      | 7 | 6 | 5 | 0.40        |
| T4      | 7 | 7 | 4 | 0.50        |
| T5      | 4 | 3 | 3 | 0.67        |
| T6      | 8 | 7 | 7 | 0.29        |
| T7      | 7 | 7 | 4 | 0.50        |

According to the results, the most critical is the transportation process with the efficiency score 0.29. There are numerous potential risks and failures in transportation process. Transport failures greatly affect delivery process and customer complaints. There are different aspects of transport failures in literature. Delayed shipping is the most important and the most frequent. The potential reasons for this mistake include the driver, congestion, wrong route calculation, etc. Damage of goods in transportation process is also important.

The next process is goods control with the score 0.33. These are problems in the warehousing process when the supplier supplies the goods of low quality and short expiration date. One of the basic steps is to define the level of quality and dimensions (specific checklists) of each unit of goods for each supplier. A relatively small number of employers in this process limit the level of control. Putting away is a very important activity in a warehouse. A large number of mistakes are generated in this process. In real systems, order pickers realize this activity. Frequently, the relocation of order pickers from picking to putting away and control process greatly affects the occurrence of failures and reduces the level of customer service. They realize this process with insufficient attention. Assigning a smaller number of employees to realize only putting away and control processes should reduce failures to minimum. Inappropriate organization of space may affect failures as well. One of the main aims is to reduce the effort in the order picking process. However, a large number of similar items at very short distances can cause failures (Andrejić et al. 2015).

The same situation is with the process of goods extraction and putting on pallets with the efficiency score 0.33. This part of order picking process is the most critical, which
confirms the value of risk priority number. There are different criteria for identification of failures in the order-picking process. According to the place of identification, there are internal (in house) and external (outside) failures. In the literature, there are four basic categories of failures: typing failures (addition, confusion, etc.), failures in amount (shortage, excess, etc.), omission failures, and condition failures (damage, lack of packaging, labeling). On the other side, there are processes with the efficiency score 1 (supplier registration, sending information about the goods inspection, etc).

4. CONCLUSION

Logistics as very complex industry with a large number of entities is threatened by numerous risks. Risks in logistics vary by system type and level of observation. For risk management in logistics, it is important to have appropriate tools and approaches. In this paper, FMEA-DEA approach for risks in logistics is proposed. The proposed approach has improved the process of calculating the RPN number in a more reliable way, since it does not require specifying the risk factor weights subjectively. The proposed approach is tested on two real cases. In organizing international commodity flows, 58 risks are identified. According to the calculated priorities, the most important risks are congestion (border, customs offices, incomplete documentation, wrong addresses (loading/unloading), etc.) In the set of 37 activities, the risks with the highest priority are: delay in transportation process, goods control (low quality, short expiration date) and order-picking process (goods extraction and putting on pallets), etc. Future research should be directed in several directions. The first direction refers to the testing of multiple, simultaneous and conditioned risks influencing the logistics. The second direction relates to determining the costs of risk management and the cost of correcting the resulting consequences. In future research, it is necessary to pay more attention to real systems and concrete cases rather than theoretical models with numerous limitations in practical application.

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