FRAMEWORK FOR IMPROVING WAREHOUSE SAFETY

Dragan Đurđević [a], Milan Andrejić [a], Nikola Pavlov [a,*]

[a] University of Belgrade, Faculty of Transport and Traffic Engineering, Serbia

Abstract: *Warehouses are a crucial component of every supply chain. They are undergoing a transition of goods flows, necessitating the implementation of intensive warehousing, transportation, and transshipment operations with products. The necessity for safety is becoming more obvious in many areas nowadays. Logistics, and especially warehousing, is one of the domains where these requirements are most prominent. The safety of warehouse work operations is divided into three categories: occupational safety, workplace safety, work safety, and fire safety. The major objective of this research was to offer a methodical approach to warehouse management and safety improvement. This method, which is based on systems analysis principles, has nine basic steps: Identification of the need for safety management, analysis of the current situation, identification of risk generators and hazards posed by generators, risk analysis, preventive and corrective measures, investments and investment effects, training staff, and periodic and continuous checks of system.*

Keywords: *safety, warehouse, methodological approach, risk, systematic analysis*

1. INTRODUCTION

Warehouses, as a component of logistics, play a vital role in the execution of supply chain process. An intentional transformation of goods flows occurs as a result of their participation in them, demanding the implementation of extensive storage, transportation, and handling operations with products (unloading, transshipment, loading, internal transport, storage, etc.). Warehouses as a whole appear to be areas where different types of accidents can occur, resulting in employee injuries or death, as well as material damage (Richards, 2018; Hofstra et al., 2018). The safety of storage operations is a complex and ambiguous topic that spans three main areas: work safety, workplace safety, and fire safety (Vukićević, 1995).

In recent years, the issue of warehouse safety has become more frequent in practice and more important. Warehouse managers are increasingly interested in providing a safe workplace environment in which the frequency of accidents resulting in increased material damage or human casualties is maintained to a minimum (Richards, 2018, De Koster 2010, Mariani, 2017). Although ideal conditions are not possible due to the nature

* n.pavlov@sf.bg.ac.rs

and characteristics of storage processes, accidents are likely to happen. However, it should be influenced so that accidents are as infrequent as possible and their effects are as minor as possible. In light of the foregoing, there is a requirement / need for increasing warehouse safety to become a continual operation. Legislation, rules, standards, good practice guides, scientific and professional papers, publications, and other resources should all be used to assist in these efforts. This document was written in the hopes of helping in that direction. The purpose of this paper is to propose a methodological framework/approach that enables the problem of warehouse safety to be set/observed in a thorough and systematic method. This varies from the majority of publications in the literature, which tackle the topic of warehouse safety in fragments, focusing only on discrete areas / aspects of the problem. On the one hand, the proposed methodological procedure in this paper is a beneficial tool for risk reduction, more efficient regulatory compliance, and a faster certification process, while on the other hand, it is a great beginning point for future research topics.

There are several parts in the paper. The second part, after the introduction, explains the issues and literature reviews. The third part outlines a methodology for improving warehouse safety. The algorithm's steps are processed within that. The objectives for safety management and an assessment of the current situation were identified first. Potential risk generators and the roles they can play were then identified. A risk analysis was also conducted, as well as proposed corrective and preventative measures to eliminate and reduce the risk. Finally, risk management investments and consequences are explored. This is a cyclical and continuous process.

2. FORMULATION OF THE PROBLEM AND LITERATURE REVIEW

2.1 Formulation of the problem

According to international sources, various warehouse accidents occur often, with levels of severity (even fatalities). At the same time, accidents in this sphere may have a significant impact on the quality of warehousing processes and thus the supply chain as a whole, in addition to the stated disadvantages related to injuries / deaths of people, damage to goods, delays in the implementation of the process (flow of goods), etc.

With the above in mind, it's worth evaluating the potential areas of risk that could be generated in warehouses with a high workload (such as trade warehouses, distribution warehouses, and etc). Furthermore, given the potential consequences, it is important for specialists in this area to consider courses of action / methods that can be used to reduce or perhaps eliminate the risks involved. As a result, there is a need for a single, easy-to-use method that can help with warehouse management and safety.

2.2 Literature review

Warehouse safety is a topic that has received much attention in the literature and in practice. The majority of academic publications deal with challenges of partial safety. Some publications focus on: (i) risk assessment only (Andrejić et al, 2020), (ii) methods (Purohit et al, 2018), (iii) only corrective actions or regulations (De Koster et al, 2011; Venkateswaran 2013), and (iv) only solving some specific safety issues (Lam et al, 2015). However, no publication examines and analyzes all of these aspects in depth, resulting in a comprehensive methodological approach for measuring warehouse safety.

Many engineers in the company, in addition to research, are working on this issue. They define a methodology for resolving limitations in the literature and enabling practical answers to specific issues. NZI Risk Solutions is one such company. They are in responsible of risk evaluations in certain warehouses. They offer advise on how to reduce risks in individual warehouses based on their practical experience. The Warehouse risk management guide (2019) is an instruction on how to handle warehouse hazards in their job. They take into account a huge number of warehouse processes and make recommendations for them based on specified standards. Fire and flood protection, protection of the working environment, protection of warehouses from external attacks, and other topics were covered.

3. METODOLOGICAL FRAMEWORK FOR IMPROVING WAREHOUSE SAFETY

Starting with the task's complexity, a logical strategy to assessing warehouse safety and removing possible risks, which is incredibly hard, is imposed. It is made up of many steps (see Figure 1): Identification of the need for safety management, analysis of the current situation, identification of risk generators and hazards posed by generators, risk analysis, preventive and corrective measures, investments and investment effects, training staff, and periodic and continuous checks of system. These steps are instructed chronologically on the diagram, but they can also be iterated.

This algorithm is the result of many years of practice and theoretical and practical research. As a result, the created methodology overcomes all of the detected issues and solves the major gaps. The following section of this paper will go over the complete algorithm with more details.

3.1 Identification of the need for safety management

It is necessary to identify the needs for risk management at the beginning of the risk analysis in the warehouse. Material damage, personnel injury, user displeasure, primary legislation, or the formation of standards are the most frequent cause. The law can refer to the Law on Workplace Safety and Health, while ISO 45001: 2018 is the most well-known standard dealing with workplace health and safety.

3.2 Analysis of the current situation (As-is analysis)

When it comes to safety, a preliminary and unavoidable analysis of the current situation is important because it identifies the need for safety management. Managers must analyze the issues that exist in the warehouse in order to analyze them and give recommendations for their solutions. They must also take into account the safety measures already in place. This assessment should include all important aspects of the warehouse that allow it to function (facilities, equipment, employees, applied technological solutions, applied safety measures and systems, etc.). The analysis' results should assist to identify issue areas, or accident generators.

There are several approaches to analyzing the current situation. Process decomposition and mapping is one of them. Interviews, surveys, checklists, field recordings, and other methods are also used. When it comes to safety, this phase is unavoidable because it identifies the need for safety management.

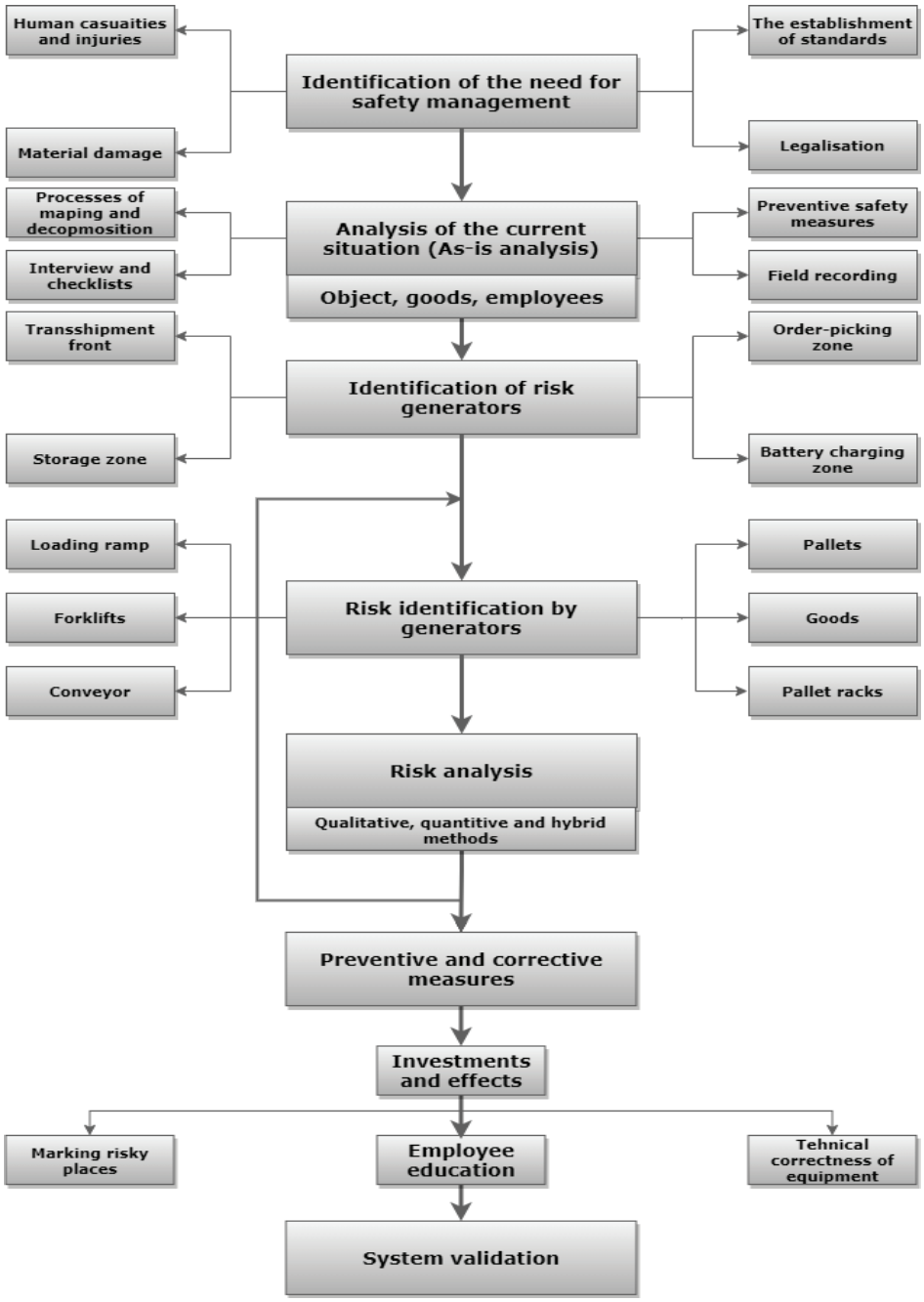

Figure 1 - A methodological approach to determining warehouse safety

3.3 Identification of risk generators

As a result of the above study, possible hazard areas were identified. Depending on the study, these risks may occur in various areas in storage system. The transshipment front, storage and order-picking zone, charging zone for forklift batteries, aisles, and other sensitive areas are frequent. Loading and unloading goods into and out of trucks and racks, storage and order picking, declaration and labeling, sorting, and other activities are managed in these zones. Some parts of the warehouse will be processed in greater detail in the future. Especially those in which there is a higher risk of damage to goods and other warehouse elements, as well as employee injuries[*].

In warehouse are performs four main processes: receiving, handling, storage, and shipment. On the transshipment front, these operations result in reciving and shipping. The transshipment front is the area of the warehouse that communicates with the outside world, allowing items to be received and dispatched to and from the warehouse. Physical, quantitative, and qualitative receiving and dispatch actions are carried out within these procedures. In technological terms, the front of palletized goods transshipment can be seen as a site / point connecting the incoming flow from the environment with the warehouse on the one hand, and the processing / storage zone with the flow from the warehouse to the environment on the other. In these situations, intensive transit and handling processes, especially in commercial warehouses, are carried out, increasing the risk[†].

In the **storage / order-picking zone**[‡], two main warehousing operations are used. These include goods storage and some types of handling. Storage goods is a static process that involves the suspension of items in order to supply some of the warehouse's basic functions (accumulation, provision of reserves, etc.). Order-picking and sorting can be done in the storage zone when it comes to processing. In addition to racks and goods, the storage zone has various transport and handling equipment (forklifts, carriages, etc.), conveyors, and employees who cooperate with warehousing operations. The specific area is characterized by storage zones with a temperature range in terms of safety (chambers). Work is carried out in these zones at extremely low temperatures, providing an uncomfortable working environment.

3.4 Risk identification by generators

Risk is defined as the possibility of a negative departure from the expected outcome. As a result, risk encompasses all factors that have the potential to positively or negatively effect the achievement of a particular goal. Risk is defined as the potential of a negative or unexpected consequence. A risk is any action or activity that results in a loss of any kind (Ivanov 2020).

The first phase of the risk management process is risk identification, which identifies risks that could affect the execution of planned activities. Internal and external factors are also

[*] https://logistikaitransport.com/wp-content/uploads/2020/02/Bezbednost-u-skladistima-White-Paper-1.pdf

[†] https://www.nzi.co.nz/content/dam/iag/nz/images/commercial/nzi/documents-and-forms/risk-solution-guides/NZI%20Warehousing%20Risk%20Management%20Guide.pdf

[‡] When storage and order-picking zones share the same storage aisles, they frequently exist in warehouses in a hybrid form generated vertically by separating the storage rack. Warehousing and order-picking activities are carried out over these zones, which creates a potential threat in and of itself.

included in the risk identification process. Identifying situations that may have a negative effect on the implementation of specific activities is known as risk identification. A number of tools are used to identify risks: Checklists, interviews, cause and effect diagrams, the Delphi method, and others are within them (Richards, 2018).

According to UK research*, most common causes of warehouse injuries are: inappropriate forklift use, improper product stacking, lack of safety equipment, frequent repetition of the same movements, and others. In addition to the usual risks, the warehouse contains a number of others. For the purposes of this paper and in accordance with the preceding point, the following components can be identified as potential areas of accident in the warehouse: loading and unloading ramp, forklifts, conveyors, pallets, goods, racks, etc. Because of the complexity of the problem, this paper will concentrate on the components of the storage system that are most involved in the implementation of storage processes and are the most common sources of accidents: transshipment fronts, pallet racks, and forklifts (Richards, 2018).

Equipment and employees generate different risks on **the loading and unloading ramps (on the transshipment front)**. The ramp can be moved independent of the vehicle. This can result in the items on the truck falling and breaking, or the entire vehicle overturning. Material damage results from the items falling and breaking, with the amount depending on the quality and quantity of the commodities, whilst the forklift flipping might result in severe bodily injury to the forklift driver in addition to material damage. Furthermore, the forklift's uncorrected speed along the ramp can have the same effect.

Forklifts are potential of being involved in a lot of accidents: falling goods from the forklift; collision of two forklifts; forklift impact on personnel; overturning; and forklift impact on static warehouse equipment just are a few examples. Forklift accidents can result in major material damage as well as human casualties (De Coster et al, 2011).

Pallet **racks** must be considered in additional to the possible causes of accidents. There are many different types of these racks, but selective pallet racks are the most typical. Because the pallet can fall out of the rack, accidents can happen. A broken pallet, a forklift blow to the rack, or poor pallet holding / disposal are some of the causes. Đurđević and Miljuš 's study on this topic provide more information (2013). Risks to generators can be represented by specific matrices. It is necessary to confront generators and risks in the matrix and determine the connection between them.

3.5 Risk analysis - strategies for calculating risk

To efficiently control risks, one must also evaluate the level of risk and whether or not it is necessary to manage this risk. There are many methods for performing such calculations today. These methods can be classified as qualitative, quantitative, or hybrid. Risk is calculated using quantitative methods as a function of the probability of occurrence and the degree of the consequences. Both elements must be expressed numerically in order to provide a thorough quantification of the risk. Qualitative approaches are dependent on the assessment maker's experience. These methods do not require knowledge of earlier activities, but they provide linguistic value (low risk, high risk, etc.). Because the probability of occurrence and the size of the risk's repercussions are difficult to determine in some situations, hybrid methods are frequently used. The

* Which she carried out OSHA (Occupational Safety and Health Administration)

matrix, tabular, and graphical methods of risk assessment are three methodologies of determining the risk of these methods. Table 1 lists some of these methods. Accident statistics can be utilized for risk analysis in addition to the methods mentioned above.

Table 1 - Most frequent risk assessment techniques.

The method's name	Consider the following factors	Form for calculating risk
KINEY method	-disease probability (V) -exposure to risks / hazards' frequency and duration (U) -consequences (P), that is, the severity of any actual risks or disease	R = V x U x P
PILZ method	-disease probability (V) -exposure to risks / hazards' frequency and duration (U) -consequences (P), that is, the severity of any actual risks or disease -number of people who are at risk (B)	R = V x U x P x B
GUARDMASTER method	-disease probability (V) -exposure to risks / hazards' frequency and duration (U) -consequences (P), that is, the severity of any actual risks or disease	R = V + U + P
FINE method	-the probability of disease or injury (P) -number of risky events (E) -possible disease or injury consequences (C)	R = P x E x C
FMEA method	-severity (S) -probability of occurrence (O) - detection (D)	RPN = S x O x D

3.6 Suggestions for risk reduction and elimination

There are numerous methodologies for reducing and eliminating risks in the warehouse, depending on type of risks. Many of these approaches can be implemented with modest financial investments while providing significant rates of return due to the efficacy of their design. The hierarchy of controls includes: (i) elimination (remove the hazard from the workplace), (ii) substitution (replace a high-risk situation with a low-risk situation), (iii) engineering controls (use technology to prevent an exposure), (iv) administrative controls (use programs or policies to prevent an exposure) and (v) PPE (as a final layer of protection). This point builds on the previous one by offering approaches to reducing the identified potential risks. Checklists can be used in the warehouse as a method of internal verification. They may be used to check the amount of safety in each warehouse rapidly and continually. Furthermore, essential areas in the warehouse must be identified and labeled. This can be accomplished by using diagrams and sketches as warnings. Preventive or corrective measures can be suggested to reduce the risk. Preventive steps are being taken to avoid accidents, while corrective actions are performed after an accident (Schwartz, 2021).

To reduce risk throughout the loading and unloading operation, the forklift's speed must first be adapted to the current conditions. It's also important that the loading / unloading ramp can resist the anticipated loads and is securely fastened to the vehicle and warehouse. When it comes to crossings and platforms, forklifts should move in the middle of them rather than on edges. Employees must adhere to defined procedures and follow established norms. One of these regulations is to enter and exit the cargo space of external transport vehicles using ladders and other aids instead of jumping out.

It is essential to influence **forklifts** when it comes to their impact on reducing risks in warehouses. In most cases, their ignorance and incompetence can result in accidents. As a result, forklift drivers must possess the requisite certificates to operate forklifts. It is also vital to adapt movement speeds to the current warehouse conditions, especially on slick surfaces and in narrow passages. Another characteristic of forklifts is their technical correctness. It is necessary to check the technical condition and monitor the wear of wearing elements on a regular basis (e.g., tires). Forklift drivers should follow the procedures for lifting, lowering, and depositing loads, but they should also consider the forklift's characteristics. To reduce the risk of personal injury, they should also use forklift seat belts. Indoor forklifts with no CO_2 emission should be used. If this is not possible, a ventilation system that minimizes the percentage of this gas in the air should be implemented*.

The majority of rack-related accidents are reported in advance. It is necessary to stack the items in them in the correct manner and, if necessary, fasten them with individual aspects in order to avoid some of the accidents. The aisles between the racks should be kept clear on a regular basis, and large goods should be placed at lower levels (Đurđević i Miljuš, 2013).

3.7 Investments and their effects

When a risk analysis determines that a deeper examination of a particular risk is necessary, preventive and corrective actions to eliminate or reduce the risk are proposed. After that, managers must calculate how much money need for execute the plan, as well as the benefits who will get. It is important for the effects to be greater than the cost in order to be rational about investing in risk elimination.

3.8 Employee education and system validation

It is necessary to conduct frequent employee training in order to improve the warehouse's safety level to an acceptable standard. Workers must be taught in order to reduce warehouse risks, based on the previous step and the definition of important points and safety procedures. Engineers suggest that employees often do not even understand the basic rules and procedures, thus this approach is preventive and primary. Especially, because employees frequently change tasks, it is vital to educate all employees with all potential risks. This phase is repeated at periodic times that are controlled by a variety of circumstances. A checklist can also be used to undertake continuous (regular) system checks.

* https://www.nzi.co.nz/content/dam/iag/nz/images/commercial/nzi/documents-and-forms/risk-solution-guides/NZI%20Warehousing%20Risk%20Management%20Guide.pdf

4. CONCLUSION

Safety has become a popular topic across many industries. As a result, the warehouse is assigned a high degree of importance. The fact that an increasing number of warehouses employ experts who deal with this issue support the conclusion. The safety of dangerous goods warehouses is especially significant. It should not, however, be ignored in traditional distribution warehouses. They have less risks and consequences, yet they can still cause significant material damage and human casualties.

There are many procedures and regulations that deal with this topic and define the rules of conduct and the manner in which goods should be managed in limited cases. Storage zones, aisles, transshipment fronts, and recharging zones for electric forklift batteries are all identified as sensitive areas where bad actions can occur when it comes to safety in distribution warehouses. It is important to pay careful attention to risks in these areas and work to eliminate or reduce them.

The methodology / procedure given in this study provides a comprehensive and methodical approach to solving problems of this nature. This procedure for identifying warehouse risks definitely minimizes risks that compromise warehouse safety, which has a direct effect on cost reduction by reducing sick leave and absence of workers, as well as the elimination of material damage to equipment. It also makes it very easy to comply with legal requirements and reduces the penalties imposed by competent inspections. It also includes a complete system implementation for the introduction of standard specifications (OHSAS and ISO 45001).

This paper can serve as a basis for further investigation in a variety of directions. The first step is to apply the proposed method to the test on real life scenarios. Additionally, the paper can be improved by inventing new risk assessment and management methods hybrid model. With certain modifications and adjustments, developed algorithm can be used for improving safety in other logistics systems and subsystems. This represents the third direction of future research. Additionally, it can be used as a decision-making tool.

REFERENCES

[1] Andrejić M., Kilibarda, M., Pajić, V. (2020). Managing risks in logistics using FMEA-DEA approach, In Quantitative Methods in Logistics, University of Belgrade, Faculty of Transport and Traffic Engineering, 49-66.

[2] De Koster, R., Balk, B. M., Davelaar, I., & Martens, M. (2010). Accidents Will Happen. Do Safety Systems Improve Warehouse Safety Performance?.

[3] De Koster, René BM, Daan Stam, and Bert M. Balk. "Accidents happen: The influence of safety-specific transformational leadership, safety consciousness, and hazard reducing systems on warehouse accidents." Journal of Operations management 29.7-8 (2011): 753-765.

[4] Đurđević, D., & Miljuš, M. (2013, November). Some safety aspects of pallet racks. In 1 st logistics international conference (p. 184).

[5] Hofstra N., Petkova B., Dullaert W., Reniers G., de Leeuw S. Assessing and facilitating warehouse safety (2018) *Safety Science*, 105, pp. 134-148.

[6] Ivanov, D. (2020). Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-

CoV-2) case. Transportation Research Part E: Logistics and Transportation Review, 136, 101922.
[7] Lam, H. Y., Choy, K. L., Ho, G. T. S., Cheng, S. W., & Lee, C. K. M. (2015). A knowledge-based logistics operations planning system for mitigating risk in warehouse order fulfillment. International Journal of Production Economics, 170, 763-779.
[8] Mariani, M. G., Curcuruto, M., Matic, M., Sciacovelli, P., & Toderi, S. (2017). Can leader–member exchange contribute to safety performance in an Italian warehouse?. Frontiers in Psychology, 8, 729.
[9] Purohit, D. P., Siddiqui, N. A., Nandan, A., & Yadav, B. P. (2018). Hazard identification and risk assessment in construction industry. *International Journal of Applied Engineering Research*, *13*(10), 7639-7667.
[10] Richards G. (2018), Warehouse management, London, UK.
[11] Schwartz, S. J. (2021). Minimizing severe injury & fatality risk in warehouse operations. Professional Safety, 66(7), 15-17.
[12] Ustundag, Alp. "Risk evaluation of warehouse operations using fuzzy FMEA." International Conference on Information Processing and Management of Uncertainty in Knowledge-Based Systems. Springer, Berlin, Heidelberg, 2012.
[13] Venkateswaran, S., Nahmens, I., & Ikuma, L. (2013). Improving healthcare warehouse operations through 5S. IIE Transactions on Healthcare Systems Engineering, 3(4), 240-253.
[14] Vukićević, S. (1995). Warehouses, Preving, Belgrade.