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TEMPERATURE CONTROLLED WAREHOUSE SAFETY MANAGEMENT MODEL

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Purpose: The primary purpose of the paper is to present the authors' own model of a temperature controlled warehouse management model. The detailed objectives of the paper is to review literature and normative acts on the subject matter and to develope a warehouse scheme as a system which provides the basis for modelling.
Design/methodology/approach: Qualitative methods of input data collection were used to build a temperature controlled warehouse management model. The data included was based on observation of the environment, auditors' experience in quality management systems, desk research, as well as an analysis of literature on the subject matter and a conceptual framework.
Findings: The model of warehouse management with temperature control takes into account static and dynamic factors resulting from the specificity of the storage process.
Originality/value: The designed temperature controlled warehouse safety management model, which applies to a warehouse where food products are stored, takes organisational, legal and technical aspects into account. The model takes into account the hazards which can affect both kinds of the presented aspects (organisational, legal and technical), which is an essential part of the model.

Keywords: model, management, warehouse, quality, hazard, risk.

Category of the paper: case study, viewpoint.

1. Introduction

Goods which require special care include products with a short expiry date, as well as perishable, non-durable and/or products whose physical and chemical characteristics are affected by their environment. In the food sector, these types of products include: foodstuffs of animal and plant origin (in their raw form and processed), confectionery, mushrooms, fish and seafood, organic agricultural products.

Storage of food products is an essential part of the whole food delivery chain, from primary production through to sales. A delivery chain represents a "network of organisations which are involved through links upstream and downstream the chain into different processes and activities that create a value in the form of products and services targeted for end customers (Stadlter and Kilger, 2008). Concerning the fact that most foodstuffs need to be stored at controlled temperatures, the issue of storage process management, including specific inputs, transformations and outputs, becomes particularly valuable and sensitive. The central aspect of the logistics of storage and distribution of products which require controlled temperatures is continuous temperature control, from accepting the goods in the warehouse until their delivery to the client. This is why a static, conventional description of a warehouse, including a presentation of its internal (organisational and functional) structures, does not suffice. One should additionally include dynamic changes which take place in the analysed warehouse and its environment, which have a significant impact on the processes (e.g. maintaining the right temperature, humidity, goods acceptance, picking or release). The operation of a warehouse should then be presented based on a combination of a static and dynamic description, useful for designing logistic simulation experiments.

The primary purpose of the paper is to present the authors' model of a temperature controlled warehouse management model, which takes into account static and dynamic factors resulting from the specific nature of the storage process. The detailed objectives of the paper, aimed at achieving the primary purpose, include a review of literature and normative acts on the subject matter and developing a warehouse scheme as a system which provides the basis for modelling. The main objective of the paper is justified by the growing need for efficient and effective management of temperature controlled warehouses. This results from the fact that, on the one hand, people eat more processed food in a form of ready-to-eat dishes, but on the other hand, they tend to choose fresh, organic food with no preservatives, which are more susceptible to the impact of unfavourable ambient conditions, e.g. during storage (Gustavsson and …, 2011). An optimum solution would be to reduce the storing of food as much as possible and to supply it to the market according to the needs. For the time being, in light of such high food overproduction, this seems a distant perspective (Griffin, Sobal and Lyson, 2009). This is where a research gap predicted for the future can be identified (Hodges, Buzby and Bennett, 2011). This is related to the subject topic of managing a temperature controlled warehouse, which contributes to the elimination of the stage in the supply chain that is nowadays an intrinsic part of food delivery to customers. Unused food (from overproduction, unnecessarily stored, which may result in its wasting) exerts unfavourable, multi-dimensional social, environmental and economic effects and has a negative influence on food safety (Lucifero, 2016). On the other hand, for many years now, we have been experiencing climate changes, which may contribute to a reduction in the crop yield by as much as 40% in some parts of the world within the next several years (Stern, 2007). This will turn the management of temperature controlled warehouses into an even more significant challenge than it is now.

2. Conceptual assumptions for the model design

Qualitative methods of input data collection were used to build a temperature controlled warehouse management model. The data included own observation of the environment, auditors' experience in quality management systems, desk research, as well as an analysis of literature on the subject matter and a conceptual framework.

The following items can be distinguished in the warehouse functioning model (including goods stored at controlled temperatures):

- **object** – a place where processes related to stock storing are executed (e.g. infrastructure: building, transport, warehouse chambers, refrigerating chambers, acceptance, storage, turnover, co-packing, release),
- **user** – a part of the reality surrounding an object, which interacts and cooperates with the object and performs it is a business (e.g. production company, service company, individual client),
- **environment** – an object and user which are related to other external elements (e.g. TSL sector transport) that affect (positively or negatively) their behaviour (effectiveness of the warehouse processes executed),
- internal and external **relations** – ability to ensure the functioning of an object (warehouse processes) and user (e.g. mega stores) and "establishment" of relations with the environment (e.g. with the suppliers and customer's market using the Internet) and influencing the situations which occur there.

The inherent properties of a warehouse, similarly to any system (object), can be analysed in the context of such values as:

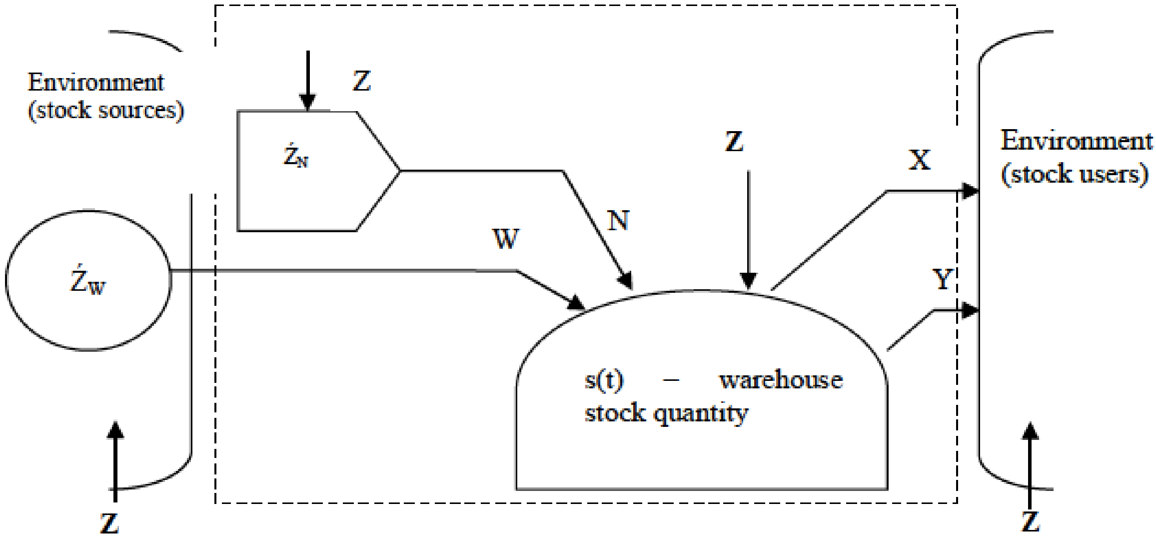
- capacity for each kind of resources,
- optimisation of warehouse stock,
- effectiveness (cost-effectiveness, productivity) of warehouse works (receipt, storage, release, record-keeping, etc.),
- the resistance of processes to interference,
- operating technical performance indices,
- warehouse operation costs.

The high number of aspects of the Warehouse Safety Management Modelling (WSMM) results in building different models based on previously planned and thought-out procedures for particular stages. During these actions, the following has to be taken into account:

a) individual stages need to be approached systemically (the components are not isolated – they are linked by relations between one another and the environment),
b) there are limitations which occur or will be occurring during modelling (e.g. availability of data from monitoring, finances, measurement capabilities, availability of procedures and computational algorithms and preparation of future users),

c) the process of WSMM construction enables periodical repeating of actions, which facilitates the return to a relevant stage of constructing a model if the results do not comply with those assumed (acquired, formulated criteria, e.g. with an acceptable level or delivery dates).

Concerning the first of the three abovementioned conditions, a warehouse which is an object of modelling can be presented as a system as shown in Fig. 1.



where:
- Ź$_W$ – stock source (a food producing company, supplier, distributor, etc.) from which the warehouse receives goods according to, e.g., contracts signed or scheduled demand;
- Ź$_N$ – stock source (e.g. goods returned by clients, products rejected by recipients because they do not meet quality standards, shipped goods returned due to external reasons beyond warehouse control);
- W – stock coming to the warehouse from Ź$_W$ sources;
- N – stock coming to the warehouse from Ź$_N$ sources in the environment, as quantities beyond warehouse control;
- X – stock leaving the warehouse as scheduled (released by the warehouse or picked by the user, e.g. according to the production schedule or contracts signed with recipients);
- Y – stock leaving the warehouse not in compliance with the schedule (e.g. not suitable for use, defective, stolen goods);
- S(t) – stock quantity in the warehouse in time t;
- Z – disturbances caused by hazards.

Figure 1. Warehouse as an object of modelling. Source: own study.

The international ISO 28000 standard of supply chain safety management harmonises global efforts towards helping organisations in such areas as production, services, warehousing and transport by limiting the risk for humans and loads. Being aware of the risk, one can assess it appropriately. Risk assessment should include the probability of an event and all its consequences (Tranchard, 2011). All actions related to warehouse management (especially a warehouse with temperature control) suffer from risks which can be caused by an emerging danger (hazards) or disturbances. The risk value (its evaluation) in the warehouse processes can be expressed in the following way (Sienkiewicz and Świeboda, 2015):

$risk = f\,(hazard,\ susceptibility,\ consequences)$ (1)

or

$VaR = P \times Sx \times P_d \times E_x$ (2)

where:

VaR – risk evaluation,
P – the probability of risk occurrence,
Sx – the value of possible losses,
P_d – susceptibility to risk which identifies the degree of warehouse susceptibility to hazards and the level of potential effects,
E_x – coefficient of exposure which identifies the degree of system (object) validity from the point of view of hazard occurrence.

In formulas (1) and (2), hazards are essential factors which significantly affect warehouse safety, and this is why it is necessary to predict their occurrence based on historical data, as well as to detect (monitor) and identify them. Data collected in this way through IT systems helps to forecast the results, predict the efforts and measures to counteract them and implement corrective measures. A correctly identified risk and the development of scenarios in case it occurs make an organisation intrinsically safer (Waters, 2011).

Warehouse safety management modelling should end with reaching a hypothetical result and the established objective. The objectives of modelling shall be defined first as subject to specific warehouse processes (i.e. receipt, storage, picking, release and documenting) and possible hazards.

Selection of a model category and determination of a structure is a stage which involves a transformation from the point of view of data modelling the objectives and knowledge of a selected warehouse and the hazards into a set of independent and non-antagonistic, incompatible and logical relations. The WSMM category selection depends on the following:

– degree of compliance with the modelled warehouse safety management in the area of safety, according to its acceptable safety level,
– ergonomics and functionality of use,
– the number of resources possessed.

The presented conditions force a compromise between the presented limitations and enables the selection of an optimum WSMM, which should provide balance between the means involved and the possible losses as a result of adverse events.

When verifying the WSMM, an essential element is to establish the criteria based on which it will be possible to evaluate whether compliance conditions correspond to the assumptions made. A positive result of evaluation completes the process of WSMM development, while a negative result means returning to previous stages of building the model. At the same time, these aspects can be treated as model constraints, requiring a high level of flexibility and sensitivity to changes in the external context of an organisation.

3. Model presentation

The developed model (Fig. 2) is presented in an iconic model form, as a graphic representation of the analysed research areas. The approach helps to understand the sense of all elements observed and facilitates learning the internal organisation of research areas. The designed temperature controlled warehouse safety management model, which applies to a warehouse where food products are stored, takes organisational, legal and technical aspects into account (Wojciechowski, 2011). There are fourteen organisational and legal aspects of the model, which include: information about the warehouse, hazard identification, interaction with the environment, management style, risk management, procedures and the way they are used, resources dedicated to counteract hazards, cost balancing, computer-assisted decisions and domestic and international requirements and standards which support safety (Walaszczyk, 2016); in other words: external and internal transport safety, occupational health and safety, human resources management and information safety. Among the eleven technical aspects of the model, there are: hazard monitoring, IT support for logistic and information systems, warehouse technical equipment, automatic identification in logistics systems, construction of the building, telematics for transport safety, monitoring of transport vehicles, monitoring and location tracking systems, laser safety systems, climate conditions measuring equipment, as well as physical and electronic safety devices in the warehouse. The model takes into account the hazards which can affect both kinds of the presented aspects, which is an essential part of the model.

Full identification of hazards through their division/classification, specifying the hazard location, duration, physical characteristics and coverage, is extremely helpful in determining the hazard "harmfulness". Warehouse operation hazards can be divided into four groups (Szymonik, 2016):

1. natural calamities and events triggered by such civilisation cause as: disasters, failures and other events resulting from human action or negligence. This group includes: fire, floods and flooding, strong winds and hurricanes, thefts at the building site, communication hazards and power grid failures;
2. events which violate the constitutional order of a country (countries), including acts of terrorism, roadblocks, illegal demonstrations, ethnic conflicts and mass migration;
3. mechanisms meant to destroy or disturb the information which is sent, processed or stored for logistic system purposes. Any disturbance in information circulation jeopardises effective and efficient logistics management along the whole supply chain, including warehouses;
4. hazards resulting from a financial crisis. Even excellent economy growth rates do not protect against a crisis, and anti-crisis instruments have still not been fully developed.

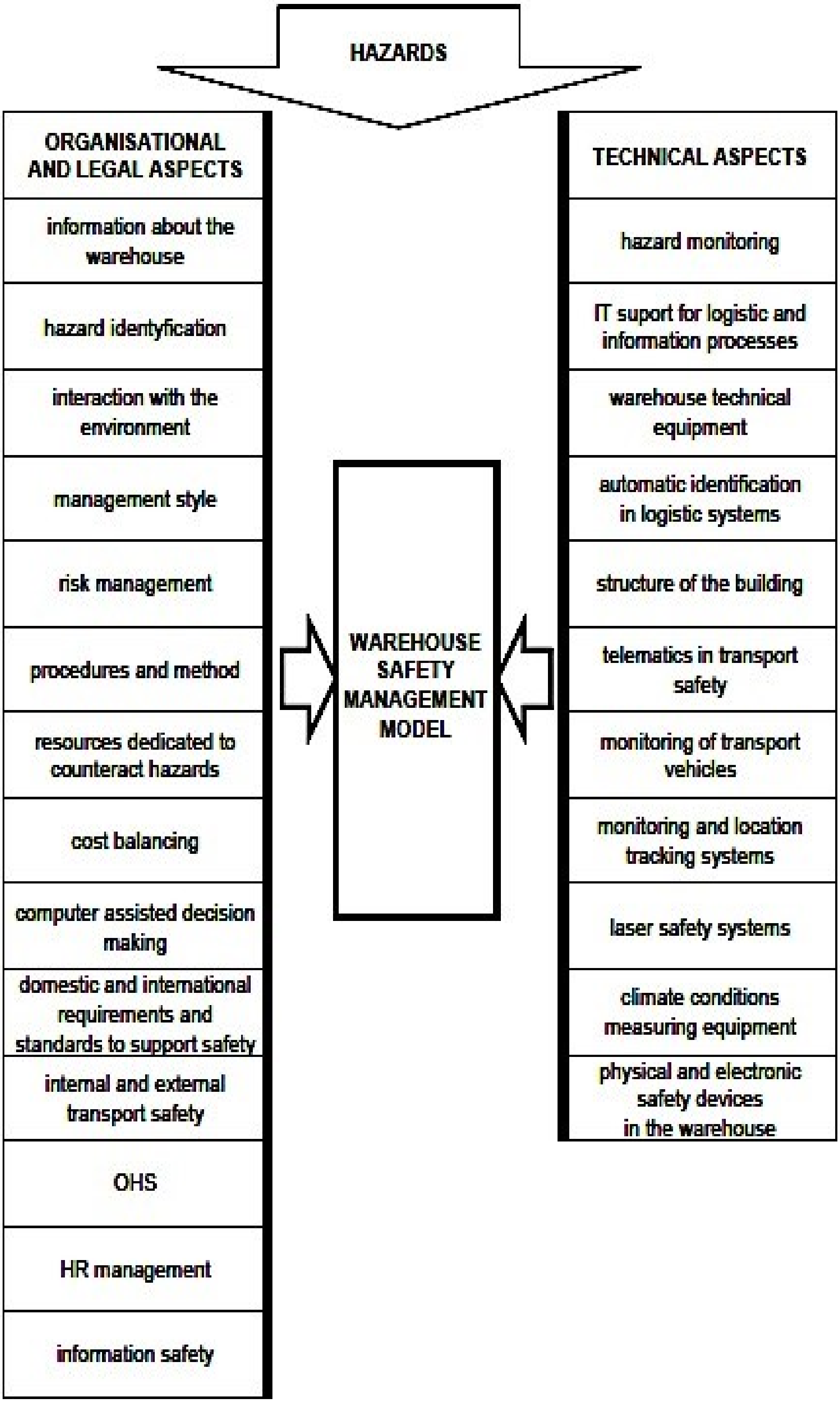


Figure 2. Warehouse safety management model. Source: own study.

There is another exciting typology of safety hazards which can be used for temperature controlled warehouse management and classifies safety hazards into three groups (Sienkiewicz, 2015):

1. human-related (bad intentions – arson, stealing of stock, dissatisfied employees, terrorists, competitors, stealing information about deliveries and customers; and with no bad intentions – accidents caused by ignorance and irresponsibility);
2. non-human related (construction disaster, failures: AC, handling system, racks, power supply, IT system) (Caputo and Pelagagge, 2009);
3. natural disasters (floods, hurricanes, earthquakes).

Regardless of the typology applied, the abovementioned hazards can have a destructive impact on all warehouse processes, especially those related to storage at controlled temperatures. This applies in particular to the human-related hazards in the context of risk caused by incompetent and non-reliable execution of tasks, as well as hazards caused by natural disasters (e.g. floods, hurricanes) and due to civilisation reasons (e.g. power failures). When a hazard strikes, the stream of goods and information is disturbed. The disturbances can be divided according to:

– place of hazard – subsystem:
  - ✓ management (e.g. ill-considered, wrong location of the warehouse, lack of full identification of hazard effects, overestimation of capacity, misinterpretation of results, lack of tools to optimise and simulate actions, not considering the growing prices of transport and energy, unexpected bankruptcies of logistic service providers, lack of systemic solutions to neutralise the effects of the lack of workforce, neglecting the hazards resulting incompetence of the staff and caused by workforce scarcity, lack of control over employees who behave non-ethically, misappropriate the property or commit other abuses, e.g. when selecting a supplier, poor stock level control system, incorrect supply/demand forecasting model);
  - ✓ sourcing (e.g. extended and non-optimum tender and sourcing procedures which engage the management too much, incoherent supplier selection criteria, supplier selection based only on the lowest price criterion, non-timely sourcing process, low quality, bad price, quantity, wrong products, bribery, corruption, no possibility to obtain the right packaging, lack of buffer stock);
  - ✓ infrastructure (e.g. difficult access to the warehouses, wrong structure of the building, incorrect number of handling means, wrong warehouse stacker cranes, faulty robbery and burglary signalling and monitoring systems, fire and hazard alarm system suffering from some drawbacks, no supervision over the cooling system - ammonia leak, engineering systems and equipment not used according to the manufacturer's technical conditions and requirements, lack of backup supply sources, lack of own MV and LV switchgear);

- ✓ handling system (e.g. wrong equipment, the incorrect arrangement of the loading unit, damage, defects, stealing of resources, lack of skilled staff, production downtimes, failures, fire, flood, disasters, falsified products);
- ✓ distribution (e.g. ignoring new products, new manufacturers, thefts, adverse weather conditions, low quality of finished products, neglecting management of customer relations and goods flow in the supply chain);
- ✓ transport (e.g. disturbance caused by fire, explosion, an accident of a means of transport, being swept overboard, no possibility to travel due to weather conditions, defective means of transport, inappropriate handling equipment, changed transport regulations, thefts, disasters),
- ✓ stock development (e.g. thefts, losses due to excess stock, fire, flood, construction disasters, power grid and IT system failures, damaged automatic identification system);
- ✓ packaging handling (e.g. products damaged in transportation due to wrong packaging, not delivering the packaging items on time due to poor weather conditions, lost packaging, environmental pollution);
- ✓ customer order service (e.g. disturbance caused by a lack of stock, wrong orders and invoices, lack of possibility to track the product location, skipping the deadlines, delivery of damaged goods to the client, no response to complaints and delays, thefts, damage);
- ✓ information (e.g. loss of confidentiality, integrity and management possibility, natural hazards such as fire, weather disturbances, static discharge, passive and active attacks, incidental errors);

– duration:
- ✓ short-term, irregular;
- ✓ long-lasting, incremental;
- ✓ recurrent, regular;

– physical characteristics:
- ✓ material (e.g. introduction of an ingredient which causes bioterrorism, low quality storage conditions resulting, e.g., from using different quality systems in the same area);
- ✓ IT-related (e.g. faults of the IT systems, automatic identification, wrong production data on the packaging);
- ✓ power-related (e.g. gas, fuel);
- ✓ non-material (e.g. financial, political or social crisis);

– coverage:
- ✓ local, related to the particular warehouse logistics, being, e.g., a single cell of a supply chain;
- ✓ extended – along the whole supply chain - in a local or global dimension;

- ✓ spreading (e.g. as a result of poisoned food delivery);
- ✓ non-spreading (e.g. as a result of preventing the dispatch of defective products to mass customers).

In order to reach the established objectives, an organisation needs to establish, implement and maintain safety management programmes. They should be optimised and include documentation which describes the assigned responsibilities, deadlines and means to achieve the objectives. Safety management programmes should be updated regularly to ensure their effectiveness and compliance with the objectives (ISO 28000:2007).

4. Summary

The characteristics of research areas and their relations presented in the model inspire further studies meant to identify the factors which contribute to providing an acceptable warehouse safety level. A temperature controlled warehouse safety level depends on a number of parameters, which can be presented qualitatively and quantitatively, creating a system of simple and complex measures.

The developed research model is complex, multi-dimensional and dynamic by nature. Designing a model for such a complex issue as managing a temperature controlled warehouse of food products is difficult and requires an extensive use of theoretical tools supported by IT technologies and the results of studies carried out on operating logistic systems. In light of the dynamics of changes on the global market, the model – similarly to any other model – needs to be approached flexibly and adapted to current market requirements resulting from the law and the needs of stakeholders, including clients, suppliers or competitors. The presented model offers such a flexible approach and the possibility to replace organisational, legal or technical aspects with other ones, if necessary, or to remove or add new aspects. Hazards require ongoing monitoring in the model. The risks resulting from the hazards have to be monitored with special attention, because they may disturb the primary process of warehouse safety management.

The issue of ensuring food safety is particularly important in the era of pandemics, e.g. COVID-19. Entrepreneurs participating in the food chain must, in connection with an emergency situation, develop new solutions, including those related to ensuring food storage. Determining the direction of research related to the impact of used technical and organisational safeguards to increase food safety is a justified direction for further research indirectly related to the issues of this study.

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