Summary of the doctoral dissertation of M.Sc. Eng. Ewelina Chołodowicz entitled "Control of distribution system with products of different shelf life under time-varying demand and delivery delays, considering system uncertainty and using single and multi-objective optimization" in the form of a collection of thematically related scientific articles

The increasing complexity of supply chains and the multitude of streams of goods flows cause a continuous need to improve methods of controlling logistics systems. Production, logistic systems and supply chains are increasingly exposed to uncertainties and risks that are directly related to the increase in the number of channels for exchanging products and information, as well as the continuous change in the dynamics of logistic entities. For this reason, it is necessary to support decisions related to the flow of goods in logistic systems.

Many inventory system models are based on simplifying assumptions such as linearity of model elements and constant delays. However, in real logistic systems, delays are variable and rarely consistent with predictions. Structural elements of logistic systems are nonlinear, for example, warehouses have limited (and non-negative) storage space, and suppliers and resources in production are limited, which consequently results in the inability to execute arbitrary control signals. Static models do not provide effective analysis of storage systems with consideration for delays and phenomena occurring within them. As logistic system structures are expanded, dynamic models have become more adequate, allowing for comprehensive analysis of the processes occurring within them. Given the similarities between strictly engineering systems and the supply chain, automation, especially control theory, can provide tools for creating effective mechanisms to optimize the dynamics of logistics processes.

The presented series of publications includes 12 articles published in scientific journals and materials from international conferences. The issues addressed include modeling the inventory systems, controlling product distribution, and optimizing this process in the face of variability and uncertainty in operational conditions. Comparative analyses were conducted to verify the proposed solutions against existing ones, also using data from real inventory systems.

In the framework of modeling the inventory system, two models are developed. The first is a linear, discrete, dynamic mathematical model of the inventory system with non-perishable products, considering the non-stationarity of delays related to the transport means used. The second model was created to address the management problem of perishable products. Compared to the first model, this one is incorporating FIFO and LIFO policies.

Furthermore, in the context of controlling and optimizing inventory systems, the focus was initially on designing systems capable of handling long-term, variable delays and fluctuating demand. To verify the developed methods, comparative analyses of control systems and applied multi-criteria optimization algorithms were conducted. Subsequently, attention was focused on developing control systems dedicated to the distribution of perishable products, taking into account uncertainties related to the spoilage process, delivery delays, and demand variability. In the presented papers, developed control systems were proposed, including a method with a PD controller and a modified structure of the Smith predictor, as well as improved methods: the periodic inventory system with an adaptive reference stock level and the perpetual inventory system with an adaptive order quantity level. To address the uncertainty of the spoilage process, a control system based on neural networks was developed. The concluding paper in the series enhanced a robust neural controller, incorporating a fuzzy estimator to adjust the number of generated orders, taking into account the forecasted demand uncertainty.

The proposed structures of the systems enable automatic order control for the inventory with a significant 28-day delay and time-varying demand. Presented analysis demonstrates that the proposed control methods achieve better results than classical methods such as the periodic inventory system, the perpetual inventory system, and the order-up-to-level controller. The proposed switching robust neural controller provides a reduction in cost function by approximately 9% compared to the neural controller. Meanwhile, the proposed robust fuzzy-neural controller significantly outperforms the classical POUT method in terms of its fill rate. The greatest advantage is observed in scenarios with lumpy demand, where the fill rate is increased by 14%.

In the presented collection of publications it was proven that the application of discrete dynamic models along with control methods, supported by modern single- and multi-criteria optimization techniques and artificial intelligence methods, enables improved order management quality in distribution systems, especially under the uncertainty associated with delivery delays and variable market demand.