Optimization of Agri-Food Supply Chain in a Sustainable Way Using Simulation Modeling

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Abstract
Poor logistical infrastructure and agri-food supply chain management leads to significant food waste in logistic system. The concept of the sustainable value added agri-food chains requires defined approach to the analysis of the existing situation, possible improving strategies and also assessment of these changes impact on further development. The purpose of research is to provide scientific substantiation of theoretical and methodological principles and develop practical recommendations for the improvement of the agri-food logistics distribution system. A case study methodology is used in this article. The research framework is based on 4 steps: Value Stream Mapping (VSM), Gap and Process Analysis, Validation and Improvement Areas Definition and Imitation Modelling. This paper presents the appropriateness of LEAN logistics tools using, in particular, Value Stream Mapping (VSM) for minimizing logistic losses and Simulation Modeling of possible logistics distribution system improvement results. The algorithm of VSM analysis of the agri-food supply chain, which involves its optimization by implementing the principles of sustainable development at each stage, is proposed. The methodical approach to the analysis of possible ways for optimizing the operation of the logistics system of the agri-food distribution is developed. It involves the application of Value Stream Mapping, i.e. designing of stream maps of the creation of the added value in the agri-food supply chain for the current and future state based on the minimization of logistic losses. Simulation modeling of the investment project on time optimization in the agri-food supply chain and economic effect of proposed improvements in logistics product distribution system functioning at the level of the investigated agricultural enterprise has been determined. Improvement of logistics planning and coordination of operations in the supply chain and the innovative pre-cooling system proposed to be introduced have a 3-year payback period and almost 75-80% probability. Based on the conducted VSM analysis of losses in the agri-food supply chain, there have been determined the main points, where it is advisable to conduct optimization changes for the achievement of positive results and the significant economic effect from the proposed measures has been confirmed. In further studies, it is recommended to focus on identifying the synergistic effect of the agri-food supply chain optimization on the basis of sustainable development.

Key words: *Logistics Distribution System, Logistic Loss, Agri-Food Supply Chain, Sustainable Development, Agricultural Products, VSM-Analysis, Simulation Modeling.*

Manuscript received March 5, 2021
Manuscript revised March 20, 2021
https://doi.org/10.22937/IJCSNS.2021.21.3.33

1. Introduction

The most important motivating factor that induces changes is the complete reorientation of Ukraine's trade relations caused by signing the agreement on the extended free trade zone between Ukraine and the EU, as well as the military conflict in the east. Over the past two years, Ukraine has reoriented exports of most agricultural products from Russia to the European Union, South Asia and South Africa. As a result of reorientation from the East to the West, Ukrainian companies are required to comply with higher standards of product quality and logistics improvement, which in its turn makes them search for the best agricultural technologies for increasing crop yields, development of the means of production, the attraction of investment, the introduction of logistic approaches to management and formation of value added agri-food chains through the involvement of the processes of post-harvest processing, storage and pre-processing.
More and more agricultural producers understand the importance of transition to the concept of sustainable development and economic production in the age of rigid economy and environmental responsibility. The concept of the lean supply chain involves implementation of the strategy aimed to reduce time required to perform operations and costs to improve efficiency. It focuses on the optimization of the processes of the entire supply chain in order to simplify it, reduce losses and processes that do not add value [1].

Unlike lean supply chains, which focus on the improvement of the customer satisfaction and reduction of losses, the "green" supply chains are aimed at searching for ways to eliminate waste in terms of environmental protection. Implementation of the LEAN-concept and sustainable development concept through "green" logistics in the activity of enterprises will have a positive impact on the environment as well as producers and consumers.

2. Analysis of Recent Research and Publications

The 2030 Agenda for Sustainable Development emphasizes the importance of markets for the achievement of sustainable development [2]. The issue of the food supply chain optimization is relevant and urgent both in the science community and in the practical domain, because the economic crisis and reorientation of the markets force agricultural producers to seek new innovative ways of economic activity. According to the estimates, the global population will reach 9 billion by 2050 [3; 4]. The most important problem is how to feed this growing population, and more essentially, how to feed it in a sustainable way. The Food and Agriculture Organization states that food production needs to be increased by 70 percent by 2050 compared to 2005-2007 levels in order to meet the future demand. Tscharntke et al. emphasize that approximately one third of all food produced globally each year becomes food waste. It is the reason to improve the agri-food supply chain in sustainable manner [5]. One of these methods is the formation of an integrated value chain on the basis of sustainable development using Lean thinking techniques [6; 7]. A number of studies justify that when using lean principles to achieve environmental production, it will bring also considerable cost benefits besides green production since Lean thinking has common goals with environmental production [8; 9; 10].

Lean Philosophy aims to reduce waste in supply chain by improving the efficiency of its processes in order to have a continuous flow of production without interruption [11]. Womack & Jones define 5 principles that serve as a base to Lean [12]. They are as follows: value, the value stream, flow, pull, perfection, but later Lean Thinking community proposed the addition of the principles "Know the Stakeholders" and "always innovate" [13]. There are several methods of representing the process flow, which help us to more easily understand the flow and identify wastes such as Value Stream Mapping (VSM) or the Waste Identification Diagram (WID) [14; 15]. Folinasa et al. note that VSM helps on identifying opportunities for Lean improvement by spotting activities that did not add value to the process [16]. They identify VSM as a visual representation of processes within a pathway that can be considered as a visual map of all the activities, which illustrate how they are linked to each other, and information such as timing and resources. In Lean thinking, the value for the client is the quality of a product or service delivered within the deadline, and which meets the customer's requirements [17]. Waste refers to everything that adds no value to the product; namely, when cost and time are added, but the client is unwilling to pay for them [18]. Seven types of waste identified by the Toyota Production System consist of Excessive Transportation, Inventory and Motion, the existence of Waiting Time, Rework, Overproduction and Defects [19]. Simboli, Taddeo, and Morgante have pointed out a new type of waste such as environmental impact [20].

Conclusions and recommendations of these scientists have a great theoretical and practical value for formation of the modern logistics distribution system and provide an opportunity to solve complex logistics problems at enterprises. However, they are fragmentary by their nature and require a holistic approach to the agri-food logistics system formation on the basis of sustainable development. In accordance with the National Strategy and Plan for the Development of Agriculture and Rural Areas [21], the main objective of the agricultural policy is to increase competitiveness of the agri-industrial complex and promote sustainable development of rural areas in accordance with the international and European standards. It is inappropriate to consider the improvement of agricultural product distribution systems without consideration of the principles of sustainable development due to the close interrelations of the agrarian sector and climatic factors.

The purpose of our research is to provide scientific substantiation of theoretical and methodological principles and develop practical recommendations for the improvement of the agri-food logistics distribution system. To achieve the goals set, the following objectives are to be accomplished:

- to assess the current state of the agricultural product distribution system (on the example of fruit and berry products), identify the main problems and prospects for the development;

- to examine and formulate value stream maps of the present and future state of the agri-food supply chain;

- to analyze links between logistic processes and indicators of their efficiency;

- to display possible results obtained due to the distribution system improvement by means of simulation modeling.

3. Materials and methods

A case study methodology is used in this article. The research framework is based on 4 steps: Value Stream Mapping (VSM), Gap and Process Analysis, Validation and Improvement Areas Definition and Imitation Modelling. The LEAN-concept [22] describes the approach to business, according to which utilization of a smaller amount of resources (including human resources, time resources, equipment, natural resources, areas) provides more business benefits (economic, environmental, social effects) when meeting consumer's needs in the best way. It involves identifying losses in the agri-food supply chain and focuses on those logistic processes that ensure the value added creation for the consumer. This concept can be used for both an individual member of the agri-food supply chain and the entire supply chain.

In order to test the LEAN principles [23; 24] and principles of sustainable development [25; 26; 27] in practice, we have developed a step-by-step plan for analyzing the logistic processes of investigated enterprises, which can be reproduced throughout the industry (like in other sectors). This involves a number of steps:

1. It is required to identify a specific consumer product that you focus on, which helps to simplify the research.
2. A coordination center consisting of the representatives of each company in the agri-food supply chain, for example, a gardening enterprise, a distribution center and retailers, should be formed.
3. It is necessary to represent all logistic processes in the system using VSM of a real-life process indicating the resources required for it.
4. It is necessary to choose the optimal variant of the improved agri-food supply chain for the whole logistics distribution system with the help of simulation modeling.

To create a common vision and choose the optimal configuration of the agri-food supply chain in the logistics system, it is necessary to display all processes of the supply chain using VSM. Under the condition of participation of all members of the agri-food supply chain in the value stream mapping of the current state, one can achieve full awareness of the current state and create a common vision of the future reference model for further development of the agri-food supply chain taking into account the interests of all interested parties.

Value stream mapping requires specification of one type of product or group of products with a subsequent representation of the whole process of delivery “from the field to the table”, since attempts of simultaneous mapping of several types of products will result in overloading with information. In our study, gardening products are taken as a basis, so we will perform value stream mapping for corresponding products, namely, pome fruits. The proposed measures on the improvement of the agri-food supply chain can be used as a sample for improving the performance of other agri-food supply chains. The research was conducted in the agri-food chain for the production and sale of fresh fruits and berries. Our goal was to increase the overall productivity of the logistics system of fruit product distribution, from the horticultural enterprise, i.e. the manufacturer that supplies the finished products to the distribution center of the retail trade system, and in its turn, it supplies products to several retail outlets in Ukraine. Simulation modeling has been used for possible economic effect estimation.

The simulation model will be constructed using the so-called Monte Carlo method. Hertz & Kupalova [28; 29] defines it as a numerical method based on the receipt of a large number of implementations of a random process, which is formed so that probabilistic characteristics (mathematical expectations, the probability of certain events, the probability of hitting the trajectory of a process in a certain area, etc.) are equal to some values of the problem, which is solved. Implementation of this method is performed in 4 stages:

1. Construction of the mathematical model of the system, which describes the dependence of characteristics of the system being modeled on the values of random factors.
2. Determination of the law of probability distribution for random factors.
3. Identification of the range of values for each random factor, the generation of values of random factors in a certain range, simulation of the system behavior through multiple simulation experiments and obtaining the evaluation of characteristics of the system being modeled (the generalization of the experiment results).
4. Estimation of the accuracy of obtained results.

4. Results

At present, the competitive priorities of the producer of fruit and berry products on the consumer market are ultra-fresh products, a large range of products, as well as the supply of green (eco-friendly) products. These factors have caused the need to introduce a stock keeping unit and the need to improve the current logistics system of product distribution. The fact that both sides got interested in deepening knowledge of the logistics process management has initiated this research. During the study we were able to compare the efficiency of the current agri-food supply chain and to optimize it based on the proposed changes. We identified the following objectives and indicators of efficiency (in descending order of significance):

1. The reduction of product deficits at retail outlets, which will lead to an increase in sales.
2. Supply of product freshness in the sales outlets.
3. Supply of the widest assortment, and, consequently, the reduction of inventory levels at retail outlets.
4. Supply of the lowest total cost of all operations throughout the supply chain.
5. Adherence to the principles of sustainable development, and minimization of resource losses.

In order to accomplish the set goals, it is necessary to reduce the level of stocks in the supply chain and to accelerate a logistics cycle of products. The level of stocks largely affects the freshness of products, the volume of losses of finished products (write-offs) and operations that do not create added value, and therefore increase costs throughout the supply chain.

At the initial stage, we need to define the limits of our map, i.e. to represent the logistical processes of the entire distribution system. So, the blocks, which conditionally denote logistic processes both within an individual enterprise and the whole agri-food supply chain, must be placed first and consistently on the map. In our research, we display the entire supply chain, so the starting and ending points for our VSM-cards will be the fruit harvesting and end-user (buyer). Logistic processes are different operations passed by products on their way to the end user; as a rule, each operation takes place on a specially designated area with the obligatory fixing of stocks at the entrance and exit.

In order to improve the logistics distribution system, it is necessary to describe thoroughly all processes that take place throughout the agri-food supply chain and analyze their relationships with other processes and effectiveness of the agri-food supply chain. All processes that create added value both within the company and throughout the agri-food supply chain need to be graphically represented in order to analyze value streams that exist at present. In other words, we must describe in details the current logistics concept of agri-food supply chain management. Table 1 lists the main characteristics of the agri-food supply chain of fruit and berry products of the case study enterprise.

The process of gathering information for each logistics operation is the most time-consuming and requires considerable efforts and communication with the representatives of the investigated enterprises.

Basic logistics operations are as follows:

- stocks;
- production cycle;
- time to adjust the equipment (time loss);
- time of full loading of the system (creation of added value);
- the number of operators (the labor force);
- the production shift;
- available net working hours;
- the waste rate;
- the package/pallet size;
- the shipment size.

Table 1: Characteristics of the logistics distribution system of enterprises

Components	Characteristics
Physical structure of the supply chain	✓ Manufacturers supply fruit and berry products to several retail outlets from the warehouse. ✓ The manufacturer and the retail center of the distribution network are located within a three-hour journey from each other. ✓ Products are stored and processed within the production capacities of the horticultural enterprise. ✓ Retail businesses are located far away from each other, which affects the transportation time.
Logistic capacities	✓ Retail outlets have limited capabilities for storage and distribution of products on the shelves. ✓ Transportation is done at the expense of carriers. ✓ The manufacturer has 1 sorting and 2 packaging lines.
Resource support	✓ Products are stored in refrigerating chambers with the controlled gas environment (CGE) with a total capacity of 17.7 thousand tons. ✓ Flexible production capacity: 2 production teams with the ability to expand to three during one day. ✓ Productive capacity of the sorting line of 1 5 tones per hour.
Products	✓ Seasonality of fruit and berry products ✓ Different yields

In addition, according to the principles of sustainable development [25; 26; 27], we consider it expedient to reflect the following indicators:

- utilized resources (water, electricity, etc.);
- emissions into the atmosphere (if any).

At the next stage, we analyze the stocks. Stocks and overproduction are the two largest sources of loss formation. Due to seasonality, it is impossible to avoid stocks in gardening, as the products are intended to be stored, but according to the statistical information of enterprises, a significant percentage of products are spoiled during storage. It is necessary to pay attention to the necessity and expediency of storing such volumes of products taking into account its quality, storage conditions, seasonal sales prices, etc.

In addition, when constructing a VSM card, it is necessary to add a time line through which you can get information about the total working time, idle time (time loss), time to create value added, etc. In addition, at each stage, information about stocks and consumer demand must be updated to calculate the amount of stocks in days and add them to the top of the time line, which will allow us to calculate the total waiting time. The production cycle (time for a particular logistics operation) of the products have been displayed at the bottom, and having it added we will get the total time of product processing.

In our study, the unit of measurement is a batch of apples, which is delivered from the garden during harvesting and consists of five containers with a capacity of 350 tons each, i.e. the total batch under the research is 1,750 kg of apples. The garden team consists of 12 workers and two tractor drivers. It takes 60 minutes to load one tractor. Then the batch is transported to the refrigerator where it is weighed and placed for further cooling. During one day, 2-3 chambers are loaded simultaneously depending on the temperature regime when removing the fruits. Before storing fruits in the CGE they must be pre-cooled to storage temperature. The average temperature of apples delivered from the garden is +25 °C. If warmed fruits are not cooled quickly, they are stored worse and lose their weight. It is critical for the farm, because the camera gets filled with a new harvest during 2-3 days.

For sorting and pre-sale preparation of apples, a sorting line that provides careful and qualitative sorting is used. When a 300-kg fruit container gets to the line, it is immediately immersed in a water tank. In the water apples come up to the surface and continue to go directly to the sorting line. Such soft and careful unloading of fruits in the water helps to prevent the damage of apples, and straightaway sort out unnecessary things if they have got into the container during harvesting (for example, leaves).

On the line the sorting team cleans apples from sub-quality fruits, then thoroughly washes fruits with running water and directs them to the automatic sorting section according to their size (caliber), color and weight. Depending on the criteria set by the operator, sorted apples get on packaging tables, where they are packed in consumer packs. The packed apples are packaged and moved to a pre-sale storage chamber where they are waiting for shipment and sale, or where they are directly loaded into the transport. The regulated gas environment is not used any longer in the pre-sale storage chamber. All the gathered information is summarized in Fig. 1, which represents VSM of the current state of the agri-food supply chain of pome fruits on the example of a separate batch of fruit products.

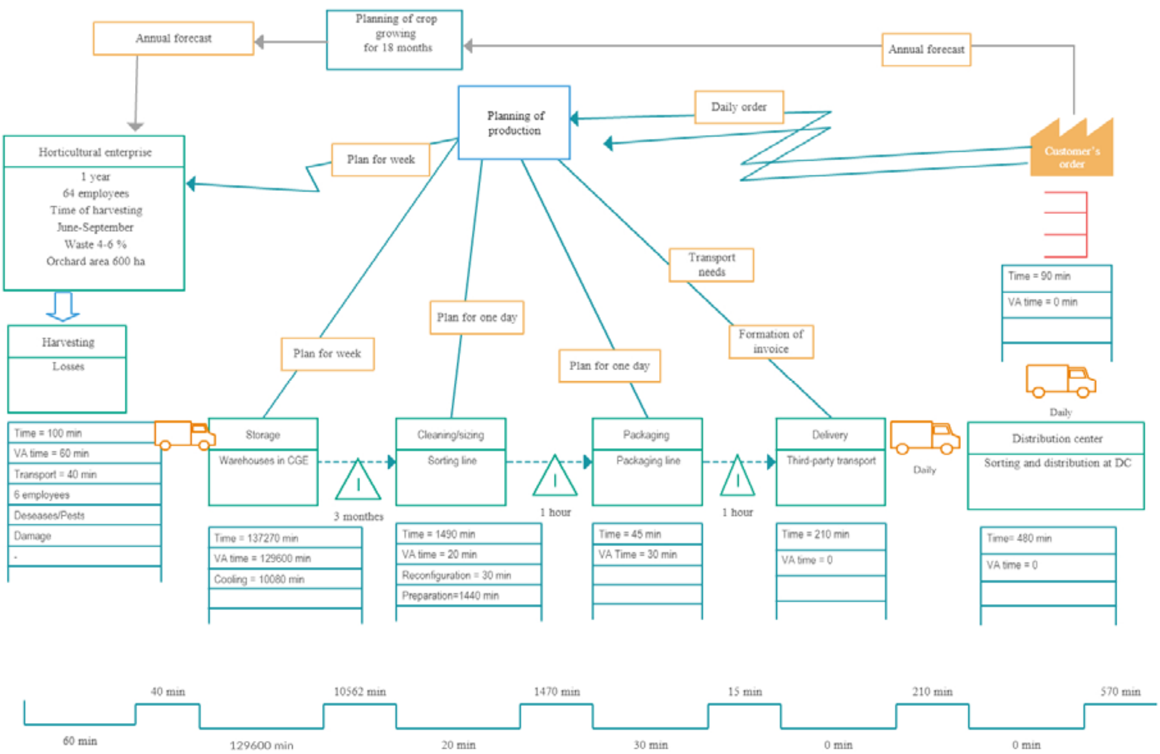


Fig. 1 VSM-card of the current state of the agri-food supply chain of fruit production

According to the data obtained (Table 2), the logistic cycle of fruit products lasts from several days to several months, and the processing time can take only a few minutes, indicating a significant time loss in the investigated distribution system.

The next step in our study is to identify shortcomings in the work of the agri-food supply chain, to identify the uncertainties that cause them and the sources of their formation. As we have already mentioned, the key indicators of agri-food supply chain efficiency are product freshness, stock levels, lack of product shortages, total ALP costs and logistic loss.

Table 2: Correlation of logistics operations regarding the added value creation (current state) at the case study enterprise

Process	Number of operations, units	Duration, min.	Duration,%
Processes of added value creation	3	93	0.065
Processes that do not add value	10	12,519	8.803
Transportation	4	342	0.239
Changeover, downtime	2	11,520	8.099
Control	1	2	0
Loading and unloading operations	4	655	0.712
Storage	1	129,600	90.882
Amount	14	142,602	100%

On this basis, we have performed Value Stream Mapping using parameters of the future state of the agri-food supply chain of fruits (Fig. 2). When constructing a map of the future state it should be considered that losses identified in the form of unproductive consumption of time, resources, products and space must be reduced maximally.

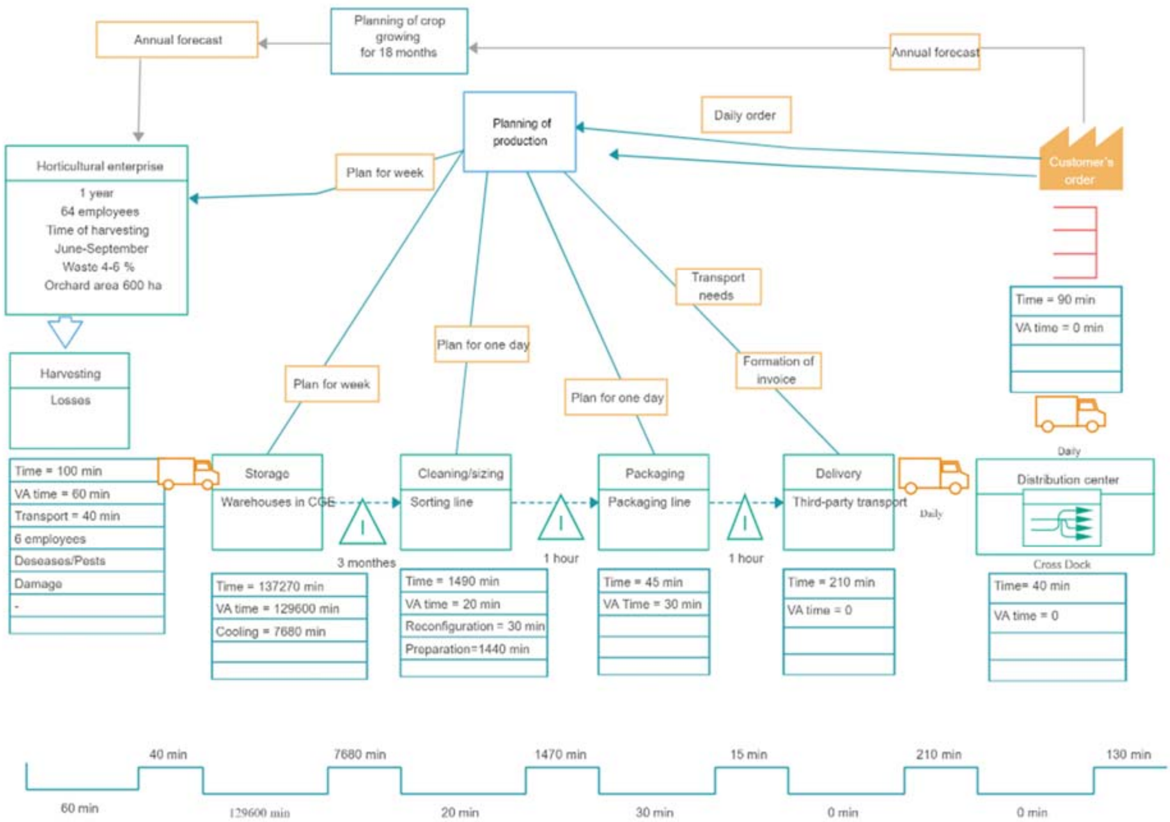


Fig. 2 VSM-card of the future state of the agri-food supply chain of fruits

Therefore, at this stage, the indicators of all parameters of the production process approximate to the ideal, i.e. the most desirable, which are also displayed in the form of a similar table. After such data generalization of the agri-food supply chain, it is necessary to consider the problems and opportunities for improvement. Hence, the vision of the ideal future supply chain will be formed in the future. This map is constructed for a medium-term period of 12-18 months.

In order to determine a possible economic effect of implementing changes in the logistics distribution system, it is necessary to identify key components that can be changed at the enterprise. After analyzing the losses of the agri-food supply chain with the help of the formed value stream mapping of current and future state, we can determine the main positions where it is advisable to carry out optimization changes or implementation in order to achieve positive results. Having conducted a preliminary evaluation of the VSM card, we have identified the critical points for optimizing the logistics distribution system:
implementation of the “cross-docking” system during sorting operations at the distribution center;
re-equipment of one of the chambers or another free space as a boiler room, which will take heat from refrigerators and transfer it to heat the floor in a room with a sorting line, which will ensure more rational use of energy. Efficiency of heat from the refrigerating chamber is 7 kw/h;
the introduction of the system of intensive pre-cooling. For this purpose there can be used a separate quick-cooling chamber with the equipment of adequate power or a mobile quick-cooling module, which is installed in the existing refrigerating chamber. Such a module is relatively inexpensive. It does not have its own refrigeration unit and consists of a powerful fan unit, several temperature sensors in pallets and tarpaulins. Fans create a dilution in the gap between the pallets, resulting in cold air from the chamber stretched through the product providing even cooling;
the establishment of the logistics department for effective logistics support both within the enterprise and for improvement of coordination and cooperation with other members of the agri-food supply chain.

Cross-docking is the process of accepting and shipment of goods directly through a warehouse without placement in the zones of long-term storage. Cross-docking is a combination of logistics operations within the supply chain, due to which shipment from the warehouse and delivery are timed as precisely as possible.

According to preliminary estimates, the application of such a scheme of operation without the engagement of the temporary structure reduces the time for the consignment processing at the enterprise from 480 to 40 minutes. This direct time saving can significantly increase the volume of traffic flow that occurs at the distribution center. A dependent increase in variable costs for the operation of the freight transport and administrative costs for the work of the logistics manager also takes place simultaneously with the system implementation.

The second key point in optimizing logistics operations is a reduction of time required for pre-cooling of fruits to the required temperature at the stage of preparation for long-term storage. The method of fruit storage in the controlled gas environment is based on the fruit storage at the relatively low temperature (0-4 °C) in the gas environment depleted of oxygen and enriched with carbon dioxide.

Practical experience shows that the use of CGE allows us to extend the shelf life of fruits, reduce their losses in mass (2 ... 3 times) without noticeable quality decrease. The success of storage in the CGE is based on the appropriate regulation of maturation processes. Thereby it slows down aging of plant tissues, decreased the damage caused by the physiological and microbiological diseases, and reduces losses. Fruits from the warehouses of CSE differ by their freshness, attractiveness, juiciness, high palatability and nutritional value. An important advantage of the storage in CSE is that the fruits are kept unharmed for 10-12 days after being transported from the chamber to the room temperature conditions. The assessment of the economic benefits provided by the higher quality of products has not been chosen as a goal of our research. The main issue is the economic effect of saving time due to intensification of the pre-cooling system.

Preliminary analysis of the pre-cooling system characteristics carried out by technical experts (the site for equipment sales) suggests that the system is capable of cooling the batch of crops of 110t from 25°C to 0°C in 24 hours, which in the calculation of the total time will reduce the time of one production cycle from 10080 minutes to 7680 minutes, which, in its turn, will accelerate the process of loading fruits in the refrigerating chambers and, therefore, will improve the quality of products and reduce the rational use of time.

In order to generalize the results we will build a table of target indicators, which will include data on the parameters of the current and future state of agricultural fruit products (Table 3).

Table 3: Comparative analysis of the current and future state of agri-food supply chain parameters

Parameters	Current state	Future state	Deviation, +/-
Time for value creation, min.	93	93	-
Transportation, min.	342	342	-
Control, min.	2	2	-
Changeover, min.	11,550	8,640	-2.910
Loading / unloading, min.	1,015	575	-440
Storage, min.	129,600	129,600	-
Total time of logistics operations, min.	142,602	139,252	-3.350
Share of product losses, %	4	0.005	-

Visualization of the reduction of time losses as a result of optimization of processes in the agri-food supply chain is shown in Fig. 3.

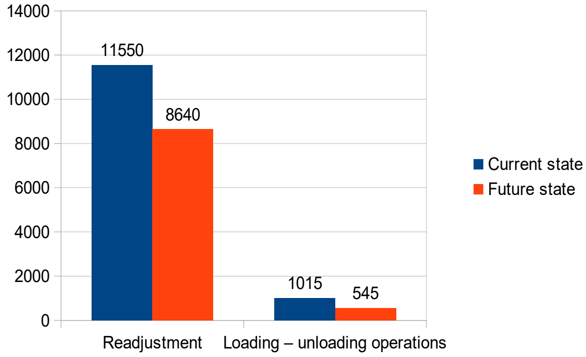


Fig. 3 The reduction of time losses as a result of logistic processes optimization, min

We know the total volume of investment required for the implementation of this system. Thus, we can calculate the economic effect of introducing an intensive pre-cooling system using the method of simulation modeling of the investment project for the optimization of time use in the agri-food supply chain.

The simulation model is an experimental model of the system, which artificially reproduces the randomness that occurs in the real system. It represents a set of mathematical relationships between input, output variables, and state variables. In order to adequately assess the economic effect under conditions of uncertainty, it is necessary to have sufficient information to formulate plausible hypotheses about probabilistic distributions of key system parameters. Since we cannot predict with high accuracy the yield and the corresponding market price of the fruits, in cases of lack of factual data, it becomes necessary to replace them with the values obtained during the simulation experiment (i.e. generated by the computer).

In accordance with the given below algorithm of actions, in the first stage we determine the dependence of the resulting indicator on the initial data. As a resultant indicator is usually one of the performance criteria, let's assume that the net future value (NFV) serves as a criterion. We will analyze the net future value (NFV) as a result of the implementation of the investment project into the system of intensification of pre-cooling of fruits by the formula:

$$NFV = \sum_{t=1}^{n} \frac{NCF_t}{(1+r)} - I_0; \quad (1)$$

where NCFt – net cash flow within a certain term t.

$$NCF = [Q(P-V) - F - A](1-T) + A \quad (2)$$

where Q – quantity of production, kg;
P – price, UAH / kg;
V – variable costs, UAH;
F – fixed costs, UAH / kg;
A – amortization of innovative equipment, UAH;
T – income tax, %;
n – full term of project implementation, years;
I0 – initial investments, UAH;
r – rate of the discount.

The key variable parameters are variable costs, output, and price. We believe that all key parameters are subjected to a single law of probability distribution. The specified ranges of possible changes of variable parameters are grouped in Table 4.

Other parameters of the project are considered to be constant values during the project implementation period. The values of variables are calculated on the basis of an expert assessment of possible predictable scenarios based on various possible situations. We have estimated permanent variables (coefficients) based on the calculations of cost estimates per unit of production of previous year.

Table 4: Key variables of the simulation modeling

Indicators	Scenarios		
	the worst scenario	probable scenario	the best scenario
Quantity, kg (Q)	128743,0	170103,0	208396,0
Price UAH / kg	8,6	14,5	17,0
Variable expenses, UAH / kg (V)	3,4	5,10	6,20

Manuscript received March 5, 2021
Manuscript revised March 20, 2021
https://doi.org/10.22937/IJCSNS.2021.21.3.33

Invariable model indicators (coefficients):

- Fixed costs – 2.50 UAH / kg (F);
- Amortization of innovative equipment – 125,416.0, UAH (A);
- Income tax – 13% (T);
- Rate of the discount – 18% (r);
- Full term of project realization – 3 years (n);
- Initial investment – 12,500, EUR (at the time of calculation of the model – 376,250, UAH) (I0).

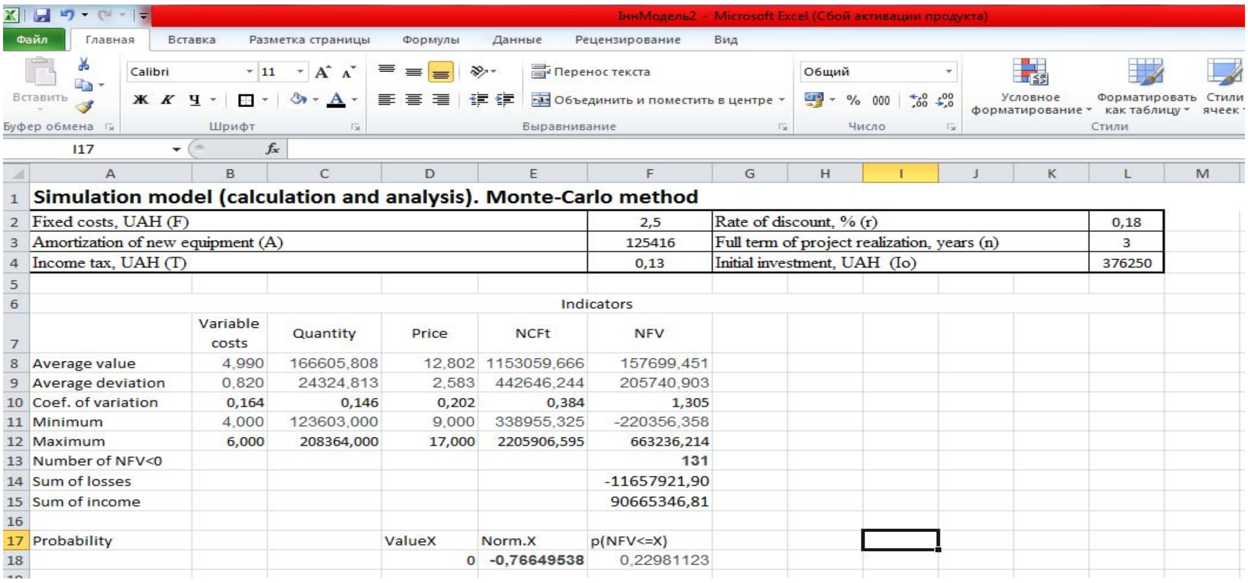
In this example, we proceed from the assumption concerning the independence and uniformity in the distribution of key variables Q, V, P. However, it is impossible to determine the distribution of effective value (NPV) in advance.

This problem can be solved by the attempt to approximate the unknown distribution by any known. As the most similar variant, it is expedient to use a normal distribution, since the sum of a large number of random variables has a distribution that approximates to normal under certain conditions, according to the central limit theorem of probability theory.

It is important to understand that when modeling the scenario we expect variable costs to grow in accordance with the volume of products sold. Therefore, variable costs (costs for operators' wages, electricity for refrigerating units, sanitary processing per kilogram of products, packaging and pallets) may increase depending on the increase in volumes rather than decrease, according to the optimistic scenario expected by the classical construction of the models of this type. Calculations for the construction and evaluation of the model will be performed by the software MO EXCEL.

Having entered the initial data, we will create a variation distribution of variables, for which the built-in function RAND(), or, in the case of the given limit values of indicators, RANDBETWEEN(), are to be used, for which we set the extreme values from Table 4 – the key variables of simulation. These variables will be randomly generated by the embedded random number generator MO EXCEL.

Indicators of the dependent variables of the reduced cash flow and net cash flow are calculated using the appropriate formulas (NCFt and NFVt). Their calculation will depend on random variables and will show us the situation in the case of the best year in terms of price conditions and yields and the worst year. The obtained general totality will be expanded to a sufficient number of experiments, in our opinion – 500. The corresponding results of the experiment analysis are shown in Fig. 4.



Simulation model (calculation and analysis). Monte-Carlo method

Fixed costs, UAH (F)	2,5	Rate of discount, % (r)	0,18
Amortization of new equipment (A)	125416	Full term of project realization, years (n)	3
Income tax, UAH (T)	0,13	Initial investment, UAH (Io)	376250

	Variable costs	Quantity	Price	NCFt	NFV
Average value	4,990	166605,808	12,802	1153059,666	157699,451
Average deviation	0,820	24324,813	2,583	442646,244	205740,903
Coef. of variation	0,164	0,146	0,202	0,384	1,305
Minimum	4,000	123603,000	9,000	338955,325	-220356,358
Maximum	6,000	208364,000	17,000	2205906,595	663236,214
Number of NFV<0					131
Sum of losses					-11657921,90
Sum of income					90665346,81
Probability			ValueX	Norm.X	p(NFV<=X)
			0	-0,76649538	0,22981123

Fig. 4 Sample deviations for 500 experiments

5. Discussion

Improved logistics planning and coordination in the supply chain and an innovative pre-cooling system that are planned to be implemented are expected to provide a payback in a 3-year period with nearly 75-80% probability. There is a rather low probability of losses in the case of simultaneous deterioration of the market conditions (falling of prices) and simultaneous decline in yields (which is hypothetically possible but unlikely).

Let's analyze the adequacy of the model with the help of built-in functions. According to the results of the correlation analysis (Table 5), the hypothesis of the independence of the distribution of the key variables V, Q, P that was moved in the process of solving the preceding example has been generally confirmed. The values of the correlation coefficients between the variable costs V, the quantity Q and the price P are close to 0. In its turn, the value of NPV depends directly on the value of the flow of payments (R = 1). In addition, there is a correlation between the average degree between Q and NPV (R = 0,384), P and NPV (R = 0,87). As expected, there is a moderate inverse correlation between the values of V and NPV (R = -0.32).

Table 5: Correlation analysis of variables

	Variable costs (V)	Yield capacity kg (Q)	Price UAH/kg (P)	NCFt	NFVt
V	1				
Q	0,074504189	1			
P	-0,093884534	0,17062044	1		
NCFt	-0,322475801	0,384317973	0,879423305	1	
NFVt	-0,322475801	0,384317973	0,879423305	1	1

Attention should be paid to the fact that close to zero values of the coefficient of correlation R show the lack of a linear relationship between variables, but they do not exclude the possibility of nonlinear dependence. In addition, a high correlation does not necessarily mean causation, since two variables studied may depend on the values of the third one. While analyzing the results of simulation modeling, the study of dependencies between key indicators is compulsory. The quantitative estimation of the variation depends directly on the degree of correlation between the random variables. Fig. 5 shows the visual (graphical) study of the relationship between key variables, namely the graph of distribution of parameters V, P and Q constructed on the basis of 50 simulations.

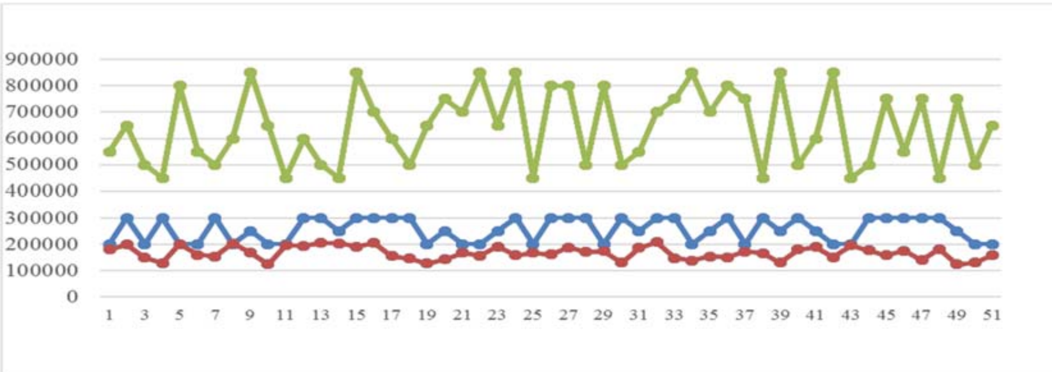


Fig. 5 Dependence between variables V, P, Q

According to Fig. 5, the variation of values of all three parameters is random, which confirms the earlier hypothesis about the independence of variables. Fig. 6 shows the graph of distribution of the flow of NCF payments and NPV value for comparison.

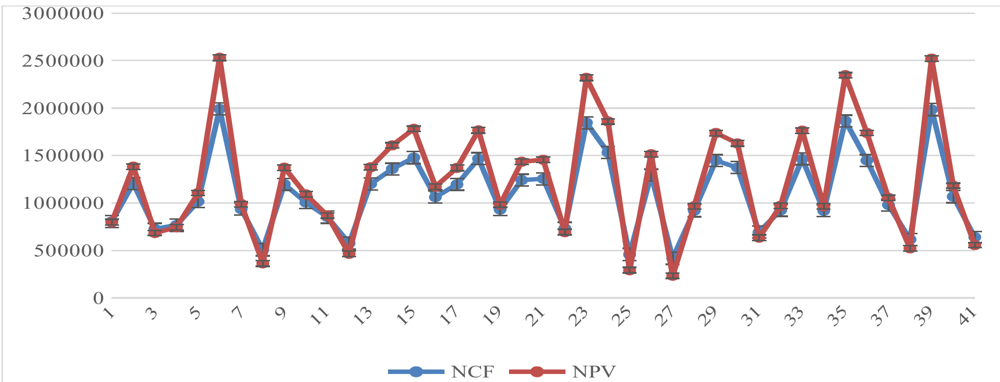


Fig. 6 Dependence between the derived variables NCF and NPV

As expected, the directions of fluctuation exactly coincide here, which indicates that there is a strong correlation relationship, similar to the functional one, between these values. Hence, it may be summed up that during the simulation experiment and subsequent probability analysis of the obtained results we have obtained positive results and a high level of the model reliability.

The present academic paper is an example of studying the introduction of VSM in a fruit company that grows and stores fruit in Ukraine. In the first stage, we have critically analyzed the production processes of the enterprise in order to identify sources of losses using Lean thinking techniques [6; 7]. After all, the methods of lean thinking can be effective tools for identifying factors that affect the supply chain of agricultural products and minimize losses [30].

The simulation was carried out taking into account the data obtained during the development of an advanced map (VSM) of the future state, which improved the efficiency of processes at the enterprise. The Monte Carlo simulation model was applied in the study, which had been also used by Rezende and Richardson [31], Mwinuka et al., [32; 33] to assess the economic performance of alternative farming systems. The feature of the Monte Carlo modeling method lies in the fact that it allows using stochastic / random variables, such as prices and yields, which cannot be clearly controlled; it is important for the agricultural sector, because it makes it possible to assess probable risks.

In addition, the study presents the current level of compatibility of LEAN practices, which includes VSM in the agri-food industry, identifying the time of operations as the most applicable indicator of efficiency. The fact that VSM tools are compatible with other tools, such as Just-In-Time and 5S, which are strategies for continuous improvement, as well as simulation that improves perception, has also been confirmed. In order to ensure the successful application of LEAN technologies aimed at minimizing food and waste losses, it is necessary to develop cooperation between all interested parties along the entire food supply chain [34].

Although this project was limited to the fruit company, the literature confirms the fact that VSM can also be applied to all other sectors with the necessary adjustments. This will have a positive effect, forasmuch as companies are looking for ways to increase the value of their products and services by eliminating the loss of resources [35]. In our study, only part of the supply chain has been analyzed; consequently, further studies of interaction with external contractors are appropriate.

6. Conclusions and Prospects for Further Developments

In the process of research and construction of Value Stream Mapping of the current and future state of the agri-food supply chain and analysis of links between logistic processes and efficiency indicators taking into account the principles of sustainable development, it has been established that the functioning of the agri-food supply chain is not optimal. There are such rare phenomena as write-offs, product losses in the supply chain, the predominance of time periods during logistics processes when no added value is created. It leads to a decrease in the efficiency of its operation. Based on the analysis of the technological process of production and the supply of products, communication with the employees of the enterprise and key players in agri-food supply chain, there has been formed a methodical approach for the analysis of ways for optimizing the logistics system of the agri-food distribution through Value Stream Mapping of the agri-food chain supply of the current and future state on the basis of the minimization of logistic losses. This method is widely used for the visualization of technological processes at industrial enterprises, however, in our research we propose to use it to optimize the agri-food supply chain. It made it possible to identify basic logistic losses. Based on the VSM analysis of losses of the agri-food supply chain, key points concerning the improvement have been determined. A significant economic effect of the proposed changes in distribution system has been proved using a simulation modeling approach. Application of the process modeling to analyze logistics operations in the agri-food supply chain and to determine a synergistic effect of its optimization taking into account economic, environmental and social factors are perspective for our further research.

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