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FINANCIAL IMPLICATIONS OF THE GREEN LEAN SIX SIGMA APPROACH IN UKRAINIAN SMALL AND MEDIUM-SIZED BUSINESSES

Keywords: Green Lean Six Sigma Method, optimization of the production, reinvestment, SME in Ukraine, financial sustainability, green investment, financial resilience.

INTRODUCTION

The change and evolution of humanity cause the need for improvement of the lives, processes, relations, businesses, etc. Due to the rapid development of artificial intelligence (AI) and large language model (LLM) technologies, the businesses' demand for developing and optimizing business processes is high. Not only huge, well-known corporations but also small and medium enterprises all around the world are eager to implement new technologies and methodologies to benefit from the enhancement they are about to make.

The missing opportunities for business result in missing profits. It is essential for big manufacturing companies as well as for small and medium-sized ones. One of the methodologies that offer a complex, well-thought and analyzed solution for the optimization problem is the Green Lean Six Sigma (GLSS) method. This research tends to elaborate on the methodology, show the different aspects and implementations of the method, and forecast the benefits of implementing the discussed approach in Ukraine. From the financial point of view of the company, the method reduces the costs and minimizes the waste of resources (including time, workforce, production etc.). Therefore, on the micro level, the companies optimize their usage of resources through the business processes. The saved resources may be allocated to other business processes to improve them accordingly. A similar effect may be expected on the macro level, the economy wins from the business improvement as it also gets more resources and profits.

The contemporary significance of the chosen topic is firstly related to the modern challenges of businesses to remain competitive and cost-efficient in the market. Secondly, the topic touches on the struggle of Ukrainian businesses, addressing not only the overall market demands and trends but also the consequent challenges of wartime and the future post-war difficulties that wait ahead. Thirdly, the GLSS method is a new combination that is still yet being discussed and described in a scientific field. The practical implications are ahead of the theoretical substantiation behind it. The research may help the households to better understand the impact of the implementation of the methodology itself or its different tools. It may also be helpful practically to estimate the missing potential for the economy from the inefficient and wasteful processes of the businesses.

The purpose of the study is to find the effect of the GLSS implementation on the production efficiency and the financial indicators of a small Ukrainian manufacturing enterprise. **The key research questions** are: (1) estimating the prerequisites of the usage of the methodology in Ukraine; (2) finding whether the implementation of the methodology may be successful and the premises for that to happen; (3) tracing and analyzing the various scenarios of the implementation and finding the threshold of investment to result ratio that is reasonable for the implementation. **The scientific novelty** of this research lies in the creation of the system that traces the dependents within the implementation of the GLSS methodology and in the creation of the system that may be used with real-life data to simulate the future success and benefits from the implementation to help with the decision-making process.

The paper consists of three main chapters: the literature review, the methods and materials, and the results. The first theoretical section begins with the history of the origin, development, and study of the GLSS methodology (1.1), followed by an examination of the financial performance changes resulting from its implementation (1.2). The fundamental tools of the method (1.3) and practical implementation examples from different companies and fields (1.4) have been reviewed, finishing with an examination of the Ukrainian literature (1.5) and a revision of the prerequisites for implementing this management philosophy among Ukrainian businesses (1.6). The second section of methods and materials generally outlines the research intent behind the model (2.1). Furthermore, it describes the statistical and programming peculiarities (2.2.1), feedback loops (2.2.2) and the variables' characteristics (2.2.3). Eventually, there is a description of the model's conditions of running and the secondary sensitivity analysis (2.3). Ultimately, the paper concludes with the results of the observant financial and employment indicators of the model (3.1), the outcome of the sensitivity analysis (3.2), and the flaws of the model that may be converted into further research projects (3.3).

Following the three defined hypotheses, the results happened to prove them all whether fully or partially. Firstly, the optimal combination of the investments in the implementation of the GLSS and the production improvement rate increases the profit by almost 70% within 10 years and decreases the number of employees by 27%. Secondly, depending on the value of the share of the profit allocated for production efficiency reinvestments, there is a difference in the outcome. With the help of the sensitivity analysis, the threshold of 25% of the profit was highlighted in the conclusion. The hypothesis of the dependency of the effectiveness of the implementation of the GLSS methodology on the efficiency gain per unit of invested currency was not fully studied in this paper and is about to be reconsidered in future works.

CHAPTER 1
THE GLSS METHODOLOGY IN THE LITERATURE

1.1 The History of the Origin, Development, and Study of the GLSS Methodology

The interest in wasteless production has increased during the past decades rapidly. Considering more climate change signs, rising costs of materials, workforce problems and so on, businesses tend to seek wider and more long-term solutions to reduce the costs, deal with rising problems of pollution, and overcome the limitedness of resources (whether they are ecological, productional, or labour ones). Moreover, businesses wish to smooth out the fluctuation of the business cycles and obtain sustainable growth and improvement. The GLSS concept here comes in handy with its benefits of sustainability and aim for wasteless production. Let us dive into the history of the emergence of the method and its forerunners.

The GLSS method is a combination of three different parts with advantages and disadvantages that were fused to eliminate the cons and increase the amount of the benefit altogether. Thus, let us look chronologically at each part separately and trace the evolution of the methodology.

After WWII, in Japan in the 1950s, Toyota came up with a way to overcome the consequences of the war and the lack of investments to deal with. With the help of the **Lean Manufacturing (LM) concept**, it could use a smaller workforce and resources in production and produce fewer errors, defects and variability in the workflow, although creating a growing variety of products. However, the term "LM" has come to see the world in the Japanese and Western performance gap of automobile construction studies of the Massachusetts Institute of Technology in the 1990s. Therefore, the Lean methodology was useful for overcoming productional defects and eliminating the waste of time, resources and potential growth [8].

Such big production companies, however, faced another problem: contamination. The LM did not take into account the elimination of pollution. Therefore, the **Green** aspect comes into play at this moment. The Green supply chain management practice may be implemented as one of the Lean ways to reduce waste and decrease carbon footprint and pollution [11]. The most well-known technique of the Green approach that is being used in production as well as in everyday life is, for instance, the 3R rule: reduce, reuse, recycle. Thus, here, we come to the combination of **Green Lean**, the overall goal of which is to implement an eco-friendly way to manufacture and increase the profitability of the production [27].

At the same time, in the 1980s, Motorola introduced and adopted the Six Sigma (SS) improvement Methodology to increase its performance and become even more competitive in the production market [3; 28]. The primary objective of the SS method is to minimize defects and variations in production. The measurement for the success of the implementation is in the number of defects per million opportunities (DPMO). The objective of the method is to reduce the number of DPMOs to as low as 3.4. The name of the concept itself refers to the statistical term of Six Sigma, therefore, the SS approach means implementing statistical tools and techniques to measure and analyze the production [4]. The SS methodology also implies the project-oriented approach which is not typical for all the mentioned above variances. Figure 1.1 shows some of them that are used in the UK industry:

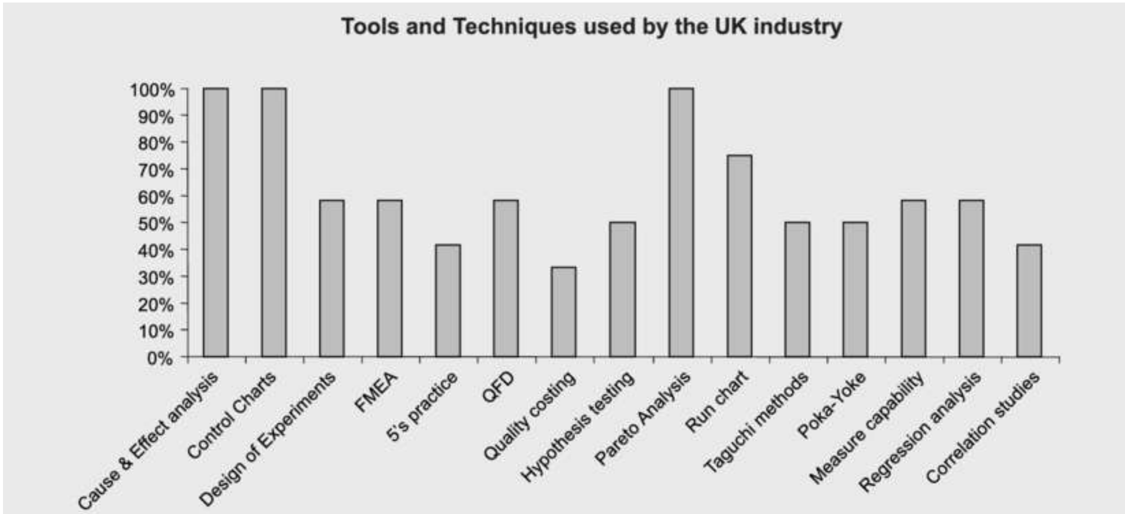

Figure 1.1 – Tools and techniques in companies practicing Six Sigma

Resource: [4].

This statistical side in Six Sigma is the thing that is absent in the LM, Green, and GL approaches. Before going to the final combination of GLSS methodology, let us also elaborate on the **Lean Six Sigma** methodology (LSS). It is a hybrid tool that has been proven to combine waste and defect reduction. In 2006 the researchers Shah, Chandrasekaran and Linderman pointed out the novelty and innovativeness of LSS as “the most recent manifestation of the process improvement evolution programmes” [24].

Although the GL and LSS methods have proved their efficiencies in their own scopes of problems, they still obtain disadvantages regarding statistical or ecological points. Therefore, the **GLLS** combination appeared just in time to mitigate the wider scope of the possible problems of different spheres whether it’s ecological or statistical ones. In the literature review of Gholami et al., 2020 work called “The Application of Green Lean Six Sigma,” the researchers compose and summarize the table of the studies conducted on this theme during 2015-2020. But it is also well understood in 2020 that the topic of this methodology is understudied, as the authors say, “new research streams are needed to advance this under-researched field…, especially the pragmatic studies that provide stepwise guidelines to implement GLSS in various industries” [27].

1.2 Financial Performance Changes Due to the Implementation of the GLSS

The financial component of the implementation is highly important and interesting for the studies. Let us touch upon the general financial benefits of the implementation and a few specific case studies conducted in different countries and different fields.

The financial performance of the company is measured by the level of usage of the firm's assets to generate revenue and profits. In the research work of Zamri et al. (2013), there is a chronological order and evolution of the studies and the thoughts on the influence of the GLSS implementation on Financial Performance (FP). It all started as just the measurement and hypothesis that the reduction of pollution causes the reduction in costs (on raw material and disposal). However, in further studies, the possible effect on revenues and the importance of it was highlighted in order to show the influence of environmental changes and innovation due to the implementation of waste reduction technologies or tools or improvements. Porter, 1995 emphasizes the importance of both sides of the balance sheet: the revenues and the costs, therefore, the research of 2011 also shows the positive relation of financial improvement, benefits, and efficacy with the motivation of the embracement of environmentally mindful practices [14].

The case studies of the financial results of the implementation of the GLSS methodology (or its separate tools) will be overviewed below.

1.3 The Key Tools and Concepts That Are Used in the Method

The methodology implies the steady and thoughtful analysis and improvement of the business operations. It is achieved through the thorough work of the implementation team. The advantage of the combined methodology is that it is more project-oriented and can be adapted for a particular case. There is a toolkit of the method that mainly consists of the Six Sigma or Lean techniques, which may be customized for environmental goals and approaches as well as used classically for the improvement of business- and workflows. Let us dive into each of the tools separately. The main techniques, tools, and philosophies lying at the base of the methodology are the following:

- Kaizen philosophy
- Define, Measure, Analyze, Improve, and Control (DMAIC) method
- Value Stream Mapping (VSM) and its customized version Ecological Value Stream Mapping (E-VSM)
- 5S System
- Regression Analysis
- Failure Modes and Effects Analysis (FMEA) etc.

1.3.1 Kaizen Philosophy

“Change for the better” or Kaizen in Japanese is a concept used in management, not only in Asia but in the Western part of the world. Its origins date back to the 1950s, and in Japan, it started as Gemba Kaizen philosophy, i.e., “Continuous improvement” (CI). The management strategy of this kind is to improve the organization constantly. It was first used in 1986 by Toyota to improve its manufacturing competitiveness and workflow. Imai introduced and implemented the technology back then. Kaizen is not simply a tool or a mechanism, it is as stated before a philosophy that covers many different well-known techniques in management like Kanban, for instance. There is a visualization of the Kaizen Umbrella introduced by Imai in 1986 (Fig. 1.2) [18].

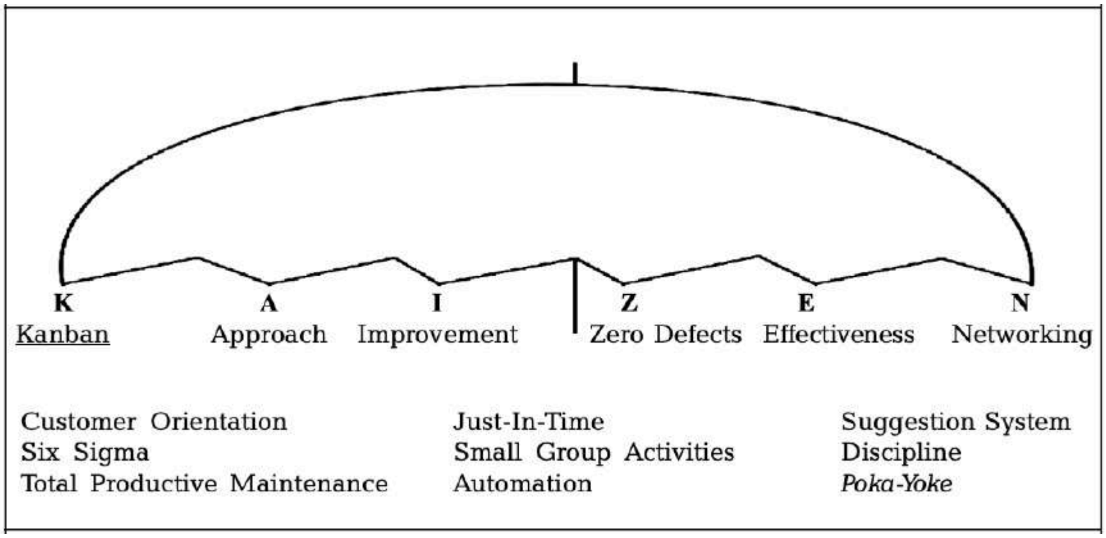

Figure 1.2 – The Kaizen Umbrella

Resource: [18].

As we can see here the Six Sigma method is also present. As we've described earlier the constant improvement, minimization of the defects and other concepts in the Figure are also typical for the Six Sigma and GLSS. The literature on this philosophy is various and with time suggests different new views and ideas on traditional techniques. Researchers describe the "Zero defects" concept of CI, different business process management requirements etc. What is more connected to the topic that is being discussed in this work, the Kaizen with lean thinking is the way to systematically and regularly reduce waste and costs.

Other researchers have gone through different potentials, benefits, and tools of CI from 1996 till nowadays [18].

1.3.2 DMAIC Method

Many researchers emphasize a difference between the approach from the theoretical point of view and the applied practical one. Even the studies of the DMAIC method may be divided into two groups: the ones based on the textbooks, theories, and courses and the ones based on practical case studies. Jeroen de Mast and Joran Lokkerbol [19] name them as prescriptive and descriptive accounts respectfully.

The DMAIC is the method that consists of five stages: Define, Measure, Analyze, Improve, and Control. Table 1.1 is built by Jeroen de Mast and Joran Lokkerbol (2012) based on the De Koning and De Mast (2006) "A Rational Reconstruction of Six Sigma's Breakthrough Cookbook" [19]. There is a detailed description of all the steps of the stages and their definition (Tab. 1.1).

Table 1.1 Rational reconstruction of the DMAIC procedure, after De Koning and De Mast (2006)

DEFINE: problem selection and benefit analysis	
D1	Identify and map relevant processes
D2	Identify stakeholders
D3	Determine and prioritize customer needs and requirements
D4	Make a business case for the project

Continuation of the **Table 1.1**

MEASURE: translation of the problem into a measurable form, and measurement of the current situation; refined definition of objectives	
M1	Select one or more CTQs [Critical to Quality]
M2	Determine operational definitions for CTQs and requirements
M3	Validate measurement systems of the CTQs
M4	Assess the current process capability
M5	Define objectives
ANALYZE: identification of influence factors and causes that determine the CTQs' behavior	
A1	Identify potential influence factors
A2	Select the vital few influence factors

IMPROVE: design and implementation of adjustments to the process to improve the performance of the CTQs	
I1	Quantify relationships between Xs and CTQs
I2	Design actions to modify the process or settings of influence factors in such a way that the CTQs are optimized
I3	Conduct pilot test of improvement actions
CONTROL: empirical verification of the project's results and adjustment of the process management and control system in order that improvements are sustainable	
C1	Determine the new process capability
C2	Implement control plans

Resource: [19].

Overall, the DMAIC is a well-defined system of implementation of improvement that is designed to target a specific problem within the process, project, or organization in general. For the entity that is eager to use this method, there is a need for a team of professionals who have competence in Six Sigma or Lean Six Sigma. The competence for its part is measured by the certification in belts (Fig. 1.3).

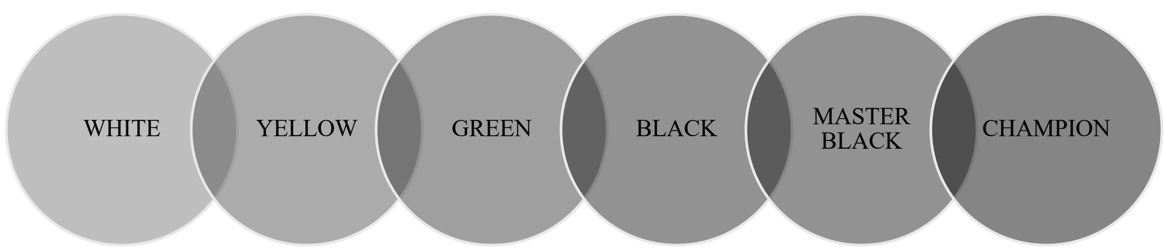

Figure 1.3 – The levels (belts) of the Lean Six Sigma Certification process

Resource: [25].

The more expertise the person gets, the higher the position in the implementation team is for them. The range starts at the White Belt and finishes with the Black for the operational roles, then there are two additional levels of Champion (preliminary) and Master Black Belt (the highest possible). As stated before, different roles are assigned in the operational team according to the colour of the belt:

- *Lean Six Sigma Champion:* the primary level of the certification. The person with this expertise is a member of the upper-level management and is responsible for creating the connection between the real objectives of the projects in the company and the business improvement ones that are about to be met with the implementation. It is not a part of the belt system but is indeed one of the most crucial roles in the improvement implementation [20].
- *Lean Six Sigma White Belt:* the first level of the Lean Six Sigma Certification process. The fundamentals of the method are explored on this level. Therefore, the individuals with this title are more about the problem-solving of local issues.
- *Lean Six Sigma Yellow Belt:* the second level of the Lean Six Sigma Certification process. The first three phases of the DMAIC method are discussed more deeply here. Individuals assert their confidence in the basics and start the path of the elimination of the defects inside the processes of the business.
- *Lean Six Sigma Green Belt:* the third level of the Lean Six Sigma Certification process. It implies the knowledge of the whole process of improvement (the DMAIC) and the assistance for the next highest-level professionals in such tasks as analyzing, solving quality issues, reviewing the statistics and analysis of the lower-tiered belts. The green belts may already be in the change-implementing teams. The certification program suggests that these experts may hold the positions of senior IT project manager, lead manufacturing engineer, operating systems specialist, project engineer, business process analyst etc.
- *Lean Six Sigma Black Belt:* the fourth level of the Lean Six Sigma Certification process. The highest level of understanding of the processes and the dynamics is what differentiates these individuals from others. They are “the agents of change” in the company and are able to implement and initiate all the aspects of the

DMAIC method for the systems and processes that need it. They are the leaders in the operational team of improvement.

- *Lean Six Sigma Master Black Belt:* the last level may be obtained after significant experience as the Black Belt expert. These are typically the senior management workers who have a deepened and much broader understanding of the concepts, philosophies and tools to be used for the improvement of each specific process and change. They may also mentor and teach the lower levels [25].

1.3.3 Value Stream Mapping (VSM) and Ecological Value Stream Mapping (E-VSM)

The Value Stream Mapping technique allows the team of analysts and implementors to look at the process flows of the production or another type of work. It is also a teamwork of professionals that explore the workflow, look for the wastes and try to visualize the results in before and after Figures. Such a tool has also another benefit of connecting the shop floor with the management team. Besides, within the process of collecting data from the production workers by the VSM team, the employees themselves may find the issues in the processes and eliminate them right away. The workers are familiar with all of the details and peculiarities of the processes, so they are to elaborate more on that if necessary. The process of questioning the shop floor is usually called "walking the flow."

The map consists of different elements that may be similar for different projects. Figure 4 below shows the common VSM icons that are used for the scheme (Fig. 1.4). The two maps are created to analyze and determine needed improvements: the current state map and the future state map. Then after the creation of the second one, the team places the kaizen sign in the place of needed improvement (kaizen burst) and eventually the draft of the plan for improvements me be suggested [29].

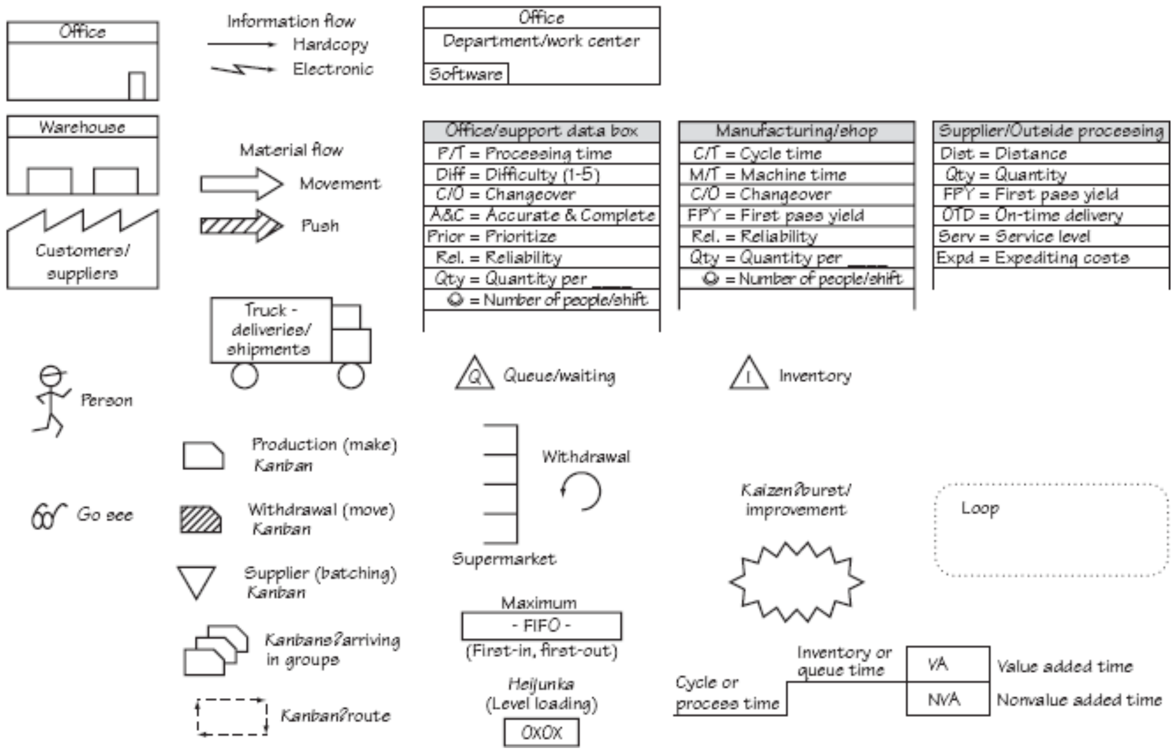

Figure 1.4 – Common VSM icons

Resource: [29].

1.3.4 5S System

This 5S methodology also comes from Japan and consists of five pillars: sort, set in order, shine, standardize, and sustain. Sometimes some other side parts are added, and the methodology consists of 7S, for instance, where the implementors attach Sustainability and Safety to the 5S system. Let us look closer at each of them:

- *Seiri (jap.) – sort:* this part implies the sorting of all the elements needed for the work (instruments, tools, even information) and arranging the workplace so that there is a minimum of the unnecessary.
- *Seiton (jap.) – set in order:* it refers to finding the most optimal order for all the necessary equipment and tools used so that the worker's workflow is constantly convenient and continuous.

- *Seiso (jap.) – shine:* the third "S" takes its origin from the Japanese working culture, where the tidiness of the workplace is essential. The constant cleaning and maintenance of neatness helps reduce the disorder and eliminate some delays and issues tied to that.
- *Seiketsu (jap.) – standardize:* the development of the standards for the orders or the processes also helps to reduce misunderstandings and absence of responsibility within the workflow.
- *Shitsuke (jap.) – sustain:* eventually, all of the above implementations are necessary to be maintained over time for the technique to have its results. It requires the controlling inspectors or just some checks once in a specific time to make sure that the changes are accepted by all the levels of production or business.

As has already been stated, there may be certain combinations for each particular case and project, therefore different other methods, besides the ones that have been described, may be helpful. A well-thought and suitable combination is the best guarantee of success of the implementation [21].

1.4 The Implementations in Different Companies and Fields: Reasons, Process, and Success

However, let us look at the implementation of the methodology closer from the practical applied point of view mainly based on the case studies.

There is a study of the implementation of the LM among different small and medium enterprises (SMEs) in the Podkarpackie Voivodship in Poland. They have researched the eagerness of the companies to implement the LM philosophy. The study was conducted among 53% medium, 33% small and 14% micro enterprises [5]. From the results, we can see that the most popular motivations to implement these low-waste changes are the intention to improve the company's operation (81%) and the intention to be more competitive (50%). Out of other grounds such as client's demands (25%), owner's demands (19%) and positive experiences of other companies (6%). Simultaneously the leader among the waste reduction desires is the waiting time for the material (49% of the enterprises), other wastes that companies wanted to eliminate are unnecessary movements (41%), machine failures (39%), nonconforming products (35%), inventory (27%) etc.

Although the method is indeed intended to be fruitful for enterprises, 58% of the analyzed companies cancelled the implementation of the philosophy due to the lack of dedication and the part of resistance from the employees on all levels, due to the lack of expertise and the individual implementation inside the company etc. Additionally, the authors highlighted the methods of the LM that were observed. Among them were the mentioned 5S (29% of companies have implemented it), Kaizen (10%), and VSM (8%).

Although the method is traditionally used to improve production and the processes of manufacture, there are also examples and case studies of the implementation of such methodology for different spheres and stages of the business cycle, such as financial processes, management processes, advertising processes etc.

For instance, in the case study of the application of Six Sigma in finance, the authors conclude that "a significant reduction in cycle time was achieved for producing the FP&A reports; specifically, the revised process resulted in 100 hours reduction in cycle time, resulting in cost savings of $130,000 per year or roughly a 64 percent reduction" [6]. Therefore, not only the production floor of the enterprises but also the management level of the SMEs could potentially benefit from the implementation of the customized different parts of the GLSS method.

If we are talking about the examples of the implementation of the GLSS method with all of the three parts (Green, Lean, and Six Sigma), there is a study of the usage of the GLSS for improving manufacturing sustainability with a step-by-step process of analysis, decision making, and implementation [15]. The authors have analyzed the literature and, in combination with experts' knowledge, proposed a framework for GLSS implementation (Fig. 1.5), which they then tested to draw implications and identify interferences.

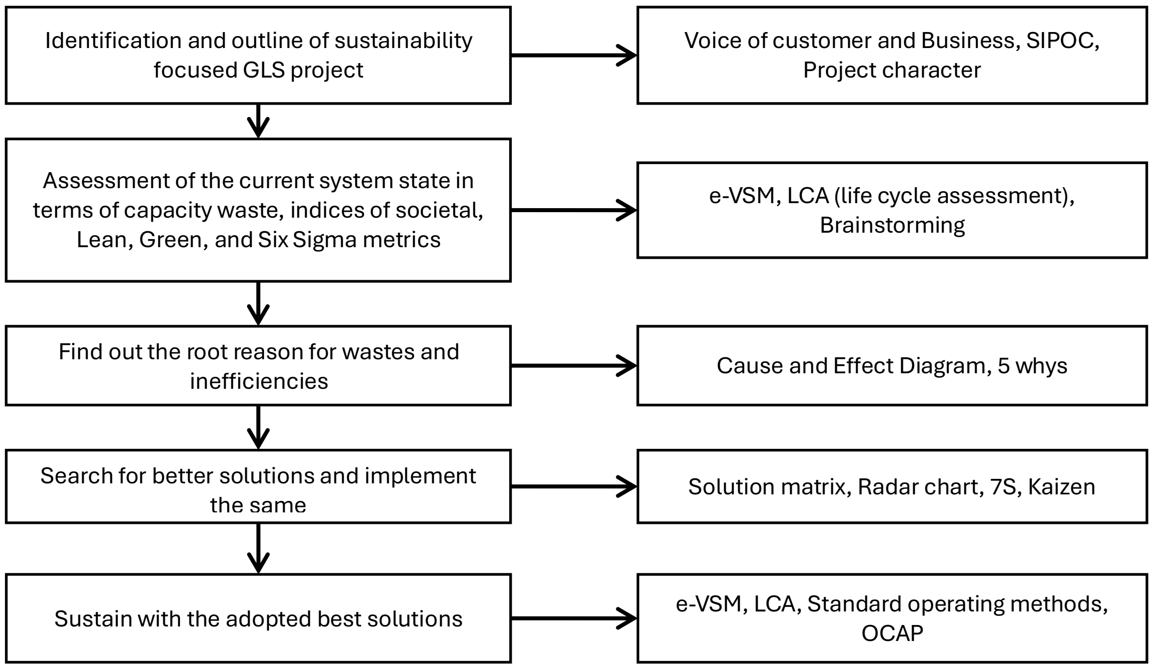

Figure 1.5 – GLSS proposed framework.

Resource: [15].

The measured benefits of the execution of the GLSS project have been shown by the researchers in the table using the metrics that were defined before (Tab. 1.2).

Table 1.2 Process metrics before and after execution of the GLSS project

Process metric	Before execution	After execution	Improvements (%) term
Cycle time	36.5 min	28.3 min	22.47%
Lead time	5 days	4.05 days	19%
Environmental footprint	26.75 Pt	19.7 Pt	26.4%

Material consumption/piece	0.713 gm	0.586 gm	17.81%
Energy utilization	4.91 Kwh	4.06 Kwh	17.31%
Coolant consumption	31 L	23 L	25.81%
Sigma level	3.62	4.01	10.77%
Capacity waste	46.3%	37.8%	18.16%

Resource: [15].

We can see that the improvements are visible throughout the whole measurement of comparison and success. Besides the production metrics, the improvements in the process have also resulted in betterment in financial indicators (Tab. 1.3). We can see that the total revenue cost increased to $358,000. There was a rework cost reduction of approximately 80% as well.

Table 1.3 Monetary benefits from GLSS execution

Metric	Before execution	After execution
Total number of components produced/ month	15000	17057
No. of parts rework/year	2172	407
Rework cost/piece	4$	4$
Total rework cost	$17,376	$3,256
Total revenue cost	$315,000	$358,000
Potential monetary saving due to GLSS project execution	$43,000	

Resource: [15].

1.5 The Ukrainian Research and Study of the Implementation of the GLSS Method or Its Parts in Different Fields

There is a lack of studies dedicated to the research of the implementation of the GLSS methodology in Ukraine. There are some mentions of the method in the literature, although, not as the main topic. For instance, in the research “Assessment of the Efficiency of Functioning of the Environmental Management System of Enterprises” where the generalized environmental quality indicators for different Kyiv districts are calculated, the application of the GLSS approach is mentioned as the way to reduce emissions and the SMEs’ waste [7].

However, there are more articles written on the topic of the Lean Six Sigma approach. For example, there is an article “The "Lean Six Sigma" System as a Tool for Improving the Quality of Business Processes and Sustainable Development of the Enterprise”, where there is a general review of the approaches and the implementation of LSS [10]. Moreover, in the article “Assessment and Enhancement of the Effectiveness of Six Sigma Methods Application in Quality Management of Production or Services” there is also a review, although, with examples of the SS approach tools implementation [9]. Talking about the implementation in the specific field, there is a research article that describes the use of the LSS methodology in the system of safety-oriented management of healthcare institutions [17]. The results of the research show that the use of LSS methodology in healthcare facilities can reduce the length and variability of patient stay and increase service throughput without significant upfront capital expenditures or ongoing resource requirements.

1.6 Economic Prerequisites for the Implementation in Ukraine

Ukraine's striving for improvement and keeping up with modern business trends is stable and increasing. Optimization can be seen in various fields. For instance, particular cases of renewable energy management in Ukraine (in particular, the hybrid energy system in the Zaporizhzhia region) show the usage of decision-making algorithms that address operational inefficiencies [12]. The two approaches studied in the research of Siasiev A., Dudnikov S., Nikolaienko D., Hubal O., and Bondarchuk O. show the reduction of prediction error by approximately 54% and rapid increases in energy loss reduction, operational cost reduction, as well as frequency fluctuation reduction by 56%, 18%, and 67%, respectively [12]. Also, the case study of the optimization processes of IT companies in Ukraine ultimately suggests the general system of optimization of the business processes for IT companies based on the comprehensive study of the existing business processes themselves [23].

In Ukraine, due to the full-scale war that russia started in 2022, a number of problems have appeared, i.e., the amount of environmental pollution has risen, there is a shortage of labour force, the risks for businesses have increased etc. For Ukrainian enterprises to survive, they should optimize their business and workflow to meet all the challenges of the time. The GLSS method has proven efficient for companies abroad, it is based on management studies and framework, therefore the implementation of it (of course, with adjustments for every particular case) may be a good option for businesses to overcome problems and collect the benefits in the future.

Let us look at the economic and societal prerequisites for the execution of the GLSS methodology in Ukraine. Firstly, all the new environmental challenges of the war notwithstanding, the amount of waste in Ukraine, even before the russian invasion in 2020 (the data on the waste in Ukraine after the year 2020 has not been published yet, so the comparison with the EU data is made of the same year), was high. In the chart below, we can see that the waste level in Ukraine is significantly higher than most of the other represented countries' levels (Fig. 1.6).

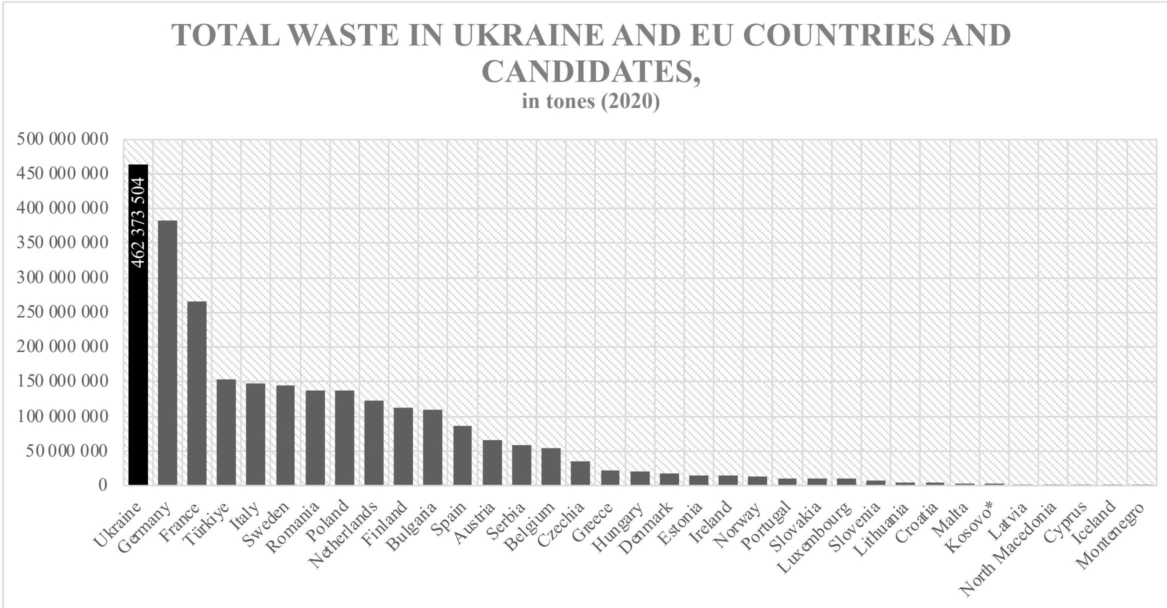

Figure 1.6. – The amount of total waste in 2020 in Ukraine and EU countries and candidates, in tones

Resource: authors' work based on the data from [26, 28].

Secondly, labour loss is another problem to be faced. It is also connected to cost-saving processes. Let us have a look at the expectations of businesses of different orientations (manufacturing, construction, retail, and services) throughout the year collected by the National Bank of Ukraine (NBU) (Fig. 1.7) [22]. The graph below shows that throughout the years among the surveyed businesses, there are more proponents (46% in February 2025) of the idea that the prices of supplies for the businesses are going to increase and more expectations (13.3% in February 2025) for the number of employees to go down. The expectation of prices of suppliers are calculated as the average of prices for raw materials for production, purchase prices (vendor prices) and cost of contractor services for construction, cost of goods purchased for sale for retail, and purchase prices (vendor prices) for services. Although the majority in both indicators sides with more neutral expectations of the absence of any changes, the overall tendency may be useful to describe the economic prerequisites for the implication of the GLSS practices among Ukrainian businesses.

When companies have a decreasing number of employees, there is likely to be a problem of not enough performers for all the processes of the business flow. This may lead both to inefficiency of the processes and the burn-out of the workers, which is also important to take into consideration. Ultimately, it may result in higher costs for labour for the company. Combing this issue with the suppliers' prices rise the cost of the processes is accelerating due to all the production costs increase. If the implementation of the suggested method happens, there is a great chance that the problem of efficiency reduction due to the issues mentioned above is about to be solved via tools of analysis and optimization offered by the GLSS process.

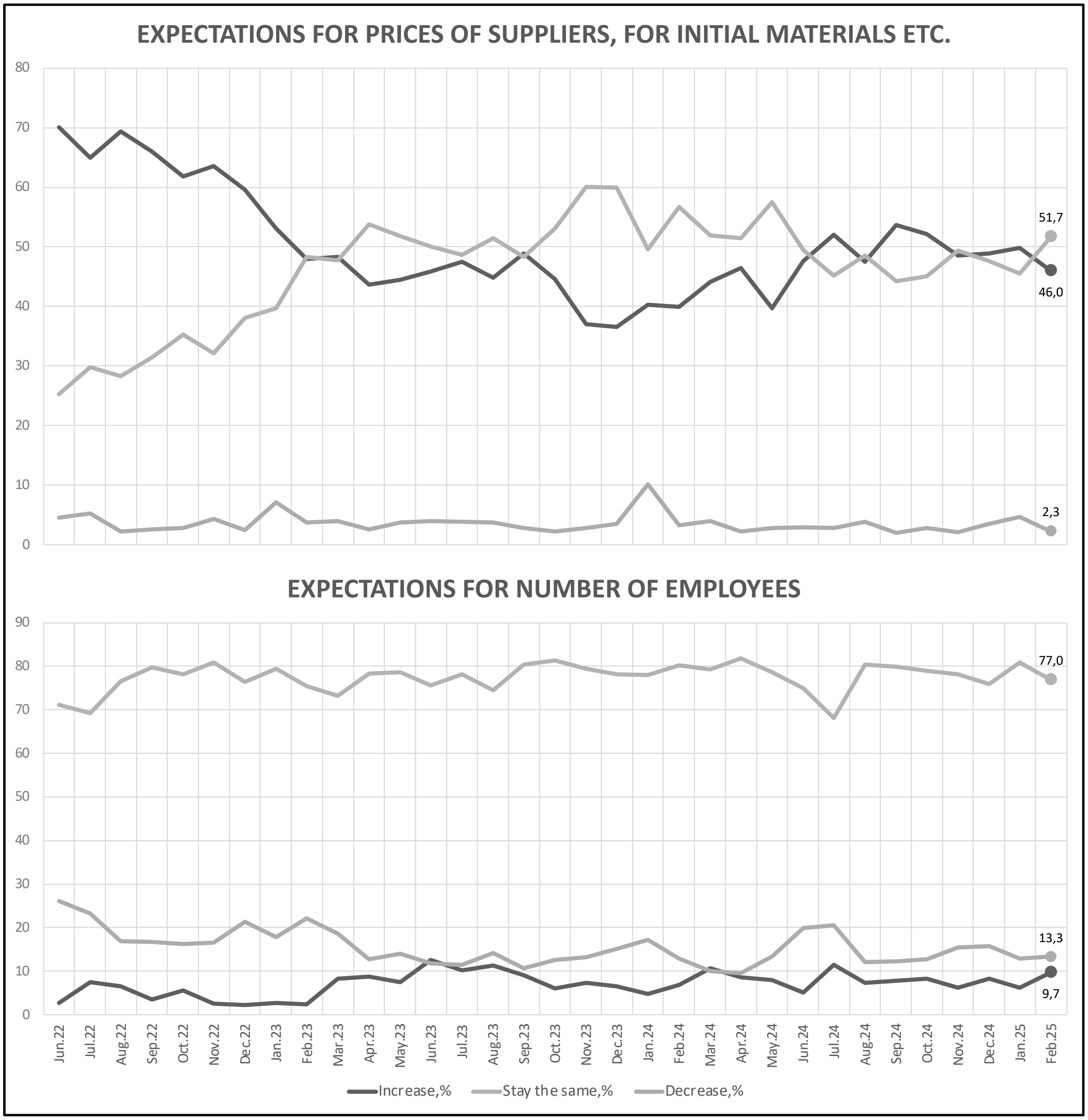

Figure 1.7 – The surveyed expectations of Ukrainian businesses on prices of supplements and the number of employees during June 2022 and February 2025, %

Resource: authors' work based on the data from [22].

In Ukraine, the techniques suggested in this method are about to be relevant not only for the same reasons of profit benefits possibilities as for abroad colleagues but also for the reduction of the consequences of the war such as higher environmental pollution, the shortage of the workforce and the increase in prices of vendors and suppliers of goods, materials and services. Ukrainian businesses of different areas should pay closer attention to the GLSS method and its separate tools.

Overall, the scientific novelty of this research is embodied in the creation of a theoretical framework that could be used in practical experiences. Besides, the study represents the development of a system that maps the dependencies involved in the implementation of the GLSS methodology. Additionally, this system is designed to integrate real-world data, enabling the simulation of future outcomes and benefits from GLSS adoption, thereby supporting more informed decision-making processes.

CHAPTER 2
BUILDING THE THEORETICAL SYSTEM DYNAMICS MODEL FOR A SMALL ENTERPRISE

2.1 General Description of the Research Questions

As previously stated, there is a lack of theoretical studies of the effects of the Green Lean Six Sigma method on production and financial indicators such as revenue or profit. Some empirical studies were mentioned in the previous chapter that show the improvements in the number of produced goods, cycle time, revenue, environmental footprint etc.

As mentioned in the literature listed above, the implementation of the GLSS method demands a significant amount of investment. Each company has its own strategy for investments and in particular reinvestments meant to improve the company's production, financial and overall performance. However, there is a traditional perception of the effect of reinvestments, where it affects the improvement of production efficiency. Foster (2007) argues that there is no need to implement Six Sigma for companies with low cash flow as the methodology effects positively the earnings, cash flow and some other Figures and ratios including the productivity in using assets, however, simultaneously requires a significant amount of investment [13]. The ratio of investments to production efficiency gain is different for every production and the sector of the manufacturing or providing of the services, therefore there is no one distinct number for it. **This is one of the research questions that is about to be faced through the sensitivity analysis. The hypothesis is that the effectiveness of the implementation of the GLSS methodology depends on the efficiency gain per unit of invested currency.** Another question is linked to the number of investments made to implement the method. **The second hypothesis is that the successful increase of the profit due to the implementation highly depends on the share of the profit or the spare available cash for investments.** If the sum invested is higher than the profit gained with the help of those investments, then there is no successful outcome of the invested money and the implementation itself. This is the question Foster (2007) mentions in his research [13]. **The third hypothesis is that the optimal combination of the investments in the implementation of the GLSS and the production improvement rate influences the profit positively and the number of employees negatively.** Therefore, it is expected to see an increase in profit and a decrease in the workforce amount by the end of the analyzed simulated period.

2.2 The Description of the Model

2.2.1 Statistical and Programming Description

In the following framework in this paper, there is a dynamics system that shows a simplified model of the production and the financial indicators in it that serve as the observant variables for the research. The results are based on the change and the variability of the financial performance of the modelled manufacturing company. Although, these changes are directly connected to the production and employment variables.

The presented model of system dynamics is made as a cycle with three accumulative connections (stocks of number of employees, production efficiency, and salary), and the instant connections that are present in the rest of the model. In the table below there are the features of the model variables (Tab. 2.1).

Table 2.1 The count of the model's variables and their features

	Variables	Stocks	Flows	Converters	Constants	Equations	Graphicals
Count	24	3	3	18	7	14	2

Resource: authors' work based on the model.

This model simulates the implementation of the GLSS methodology to improve company profit while reducing workforce through investments in production efficiency. It represents a complex system with several interconnected feedback loops to trace the dependents and answer the research questions of the work (Fig. B.1).

The model was built in the Stella Architect (the modelling tool to create simulations and system dynamics models). There are run specs in the model that are essential for the program to run the simulation correctly and accurately (Tab. 2.2).

Table 2.2 Run specs of the model in Stella Architect

Run Specs	
Start Time	2025
Stop Time	2035
DT	1/400
Time Units	Years
Save Interval	0,0025
Integration Method	Euler
Keep all variable results	True
Run By	Run
Calculate loop dominance information	True
Exhaustive Search Threshold	1000

Resource: authors' work based on the model.

Let us explain all the significant features of the run specs. The simulation begins in the year 2025 (start time) and ends in the year 2035 (stop time). The DT (delta time) means that the simulation uses a time step of 1/400 years. This is used for high accuracy of the run, meaning calculations are updated 400 times per year (the time unit used in the model). The results are saved every 0,0025 years (save interval), which provides the needed frequency of data points for the analysis. The Euler method is used as the integration method for numerical integration, which is a straightforward and commonly used approach for time-stepped models. All the other features are set by default for the program to run the simulation easily for interpretation and observation.

2.2.2 Feedback Loops in the Model

There are three major feedback loops in the model (Fig. 2.1): two balancing and one reinforcing loop (workforce reduction balancing loop, salary inflation loop, and efficiency investment reinforcing loop). They drive the changes in the main variables in dynamics.

Workforce Reduction Balancing Loop:

$$Production\ efficiency \rightarrow Desired\ employment \rightarrow Workforce\ reduction\ rate \rightarrow Number\ of\ employees \rightarrow Labour\ cost \rightarrow Total\ cost \rightarrow Profit$$

The first balancing loop shows the dynamics of the number of employees depending on production efficiency. As efficiency increases, fewer employees are needed, reducing labour costs and increasing profits.

Salary Inflation Loop:

$$CPI\ change \rightarrow Salary\ gain \rightarrow Salary \rightarrow Labour\ cost \rightarrow Total\ cost \rightarrow Profit$$

This balancing loop shows how inflation affects salary costs and ultimately impacts profitability.

Efficiency Investment Reinforcing Loop:

$$Profit \rightarrow Sum\ invested\ in\ production\ efficiency \rightarrow Effect\ on\ production\ efficiency \rightarrow Efficiency\ improvement\ rate \rightarrow Production\ efficiency \rightarrow Production \rightarrow Revenue \rightarrow Profit$$

This positive feedback (reinforcing) loop shows how reinvesting profits leads to higher efficiency, increasing production and revenue, and generating more profit for further investment.

2.2.3 The Variables and Their Specs

In Appendix A, there is a table with the variables, their equations or values, properties and units (Tab. A.1). Let us go through every variable and the data and conceptions that lie underneath.

As already mentioned above, there are three stocks: number of employees, production efficiency, and salary. There are three flows: two inflows (efficiency improvement rate and salary gain) and one outflow (workforce reduction rate). And, eventually, there are eighteen exogenous variables. The simulation does have some hypothetical data values and some predicted ones. Let us go through each variable and its values as they are listed in Table A.1.

1. **The share of the profit allocated for investment into production efficiency improvement through the implementation of the GLSS *(%_of_profit_for_investment).*** The share for the initial simulation is defined as 0,4 because the implementation of the method requires a lot of investments, therefore, the percentage is quite high (40% of the profit). Further in the paper, the sensitivity analysis is to be conducted to estimate the change in financial results with the various values of this variable.
2. **Adjustment time for efficiency improvement *(adjustment_time_for_efficiency_improvement).*** The variable stands for the period that is required in the simulated production for production efficiency to change due to improvement within the process of implementation of the GLSS. In the system, this period equals 3 years, which corresponds with the general average time when the results may be seen in the production efficiency.
3. **Adjustment time for workforce *(adjustment_time_for_workforce).*** The variable is also the period of adjustment but for the workforce in this case. The value is 1 year with the assumption that the workforce is about to adjust faster to the change in management techniques. There is also an underlying hypothesis that for the company, the HR changes are easier to make than, for instance, making some structural changes to production or warehouse equipment.

4. **Change of the consumption price index in Ukraine *(cpi_change)*.** The variable serves as the "natural" driver for the salary increase considering that inflation is present in the real world, the simulation also considers it with the help of this variable. There is available data on the yearly CPI change for the previous periods starting from 2006 until 2024 (Tab. 2.3) [16].

Table 2.3 Data on CPI and CPI change in Ukraine (2005-2024)

YEAR	CPI_INDEX	CPI_CHANGE, %
2005	49,34	
2006	53,81	9,05
2007	60,72	12,84
2008	76,03	25,23
2009	88,11	15,88
2010	96,37	9,37
2011	104,03	7,96
2012	104,63	0,57
2013	104,38	-0,24
2014	116,98	12,07
2015	173,94	48,70
2016	198,14	13,91
2017	226,75	14,44
2018	251,58	10,95
2019	271,43	7,89
2020	278,84	2,73
2021	304,95	9,36
2022	366,50	20,18
2023	413,59	12,85
2024	440,48	6,50

Resource: authors' work based on the data from [16].

To consider the future periods, the predictions for the simulated years were made. In this case, the Autoregressive Integrated Moving Average (ARIMA) model using Python programming language was built to make a forecast of the CPI change. There are a few problems with forecasting the CPI change in Ukraine. Firstly, there is a limited small amount of the data. It leads to the possible lack of information for the model to make predictions and trace the patterns. Secondly, the fluctuations are significant in the CPI change in Ukraine not because of the patterns or the consistent seasonality, but due to the economic and political shocks that have followed the country since the independence. Therefore, the period of 2017-2024 was chosen to avoid accounting for the previous economic shocks (Fig. 2.1). We may assume that the end of the russian-Ukrainian war will lead to another economic shock, therefore, we may accept the previous fluctuation due to the beginning of the full-scale invasion for the model to train on.

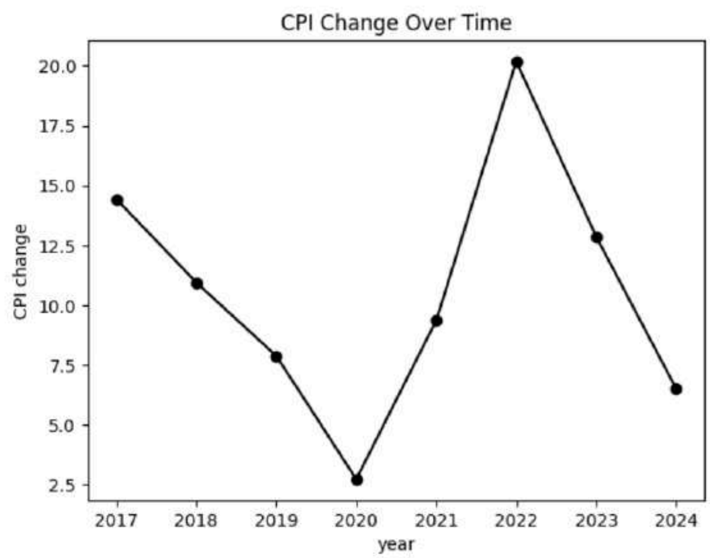

Figure 2.1 – The CPI change over time in Ukraine (2017-2024), %

Resource: authors' work from the Python code and based on the data from [16].

The best statistical model based on the Akaike Information Criterion (AIC) was selected automatically according to the results of the code, which tries out different ARIMA model orders and chooses the one with the lowest AIC. In this case, the AIC is 141,24 with the order of ARIMA (9, 0, 0). The lower the AIC for the model, the better the model is. However, the program chooses the lowest value out of all the possible variants; therefore, 141,24 is the best criterion available here, which indicates a relatively good fit to the data. The results can be seen in Table 2.4 and in Figure 2.2 compared with the historical data from 2017-2024 on one graph.

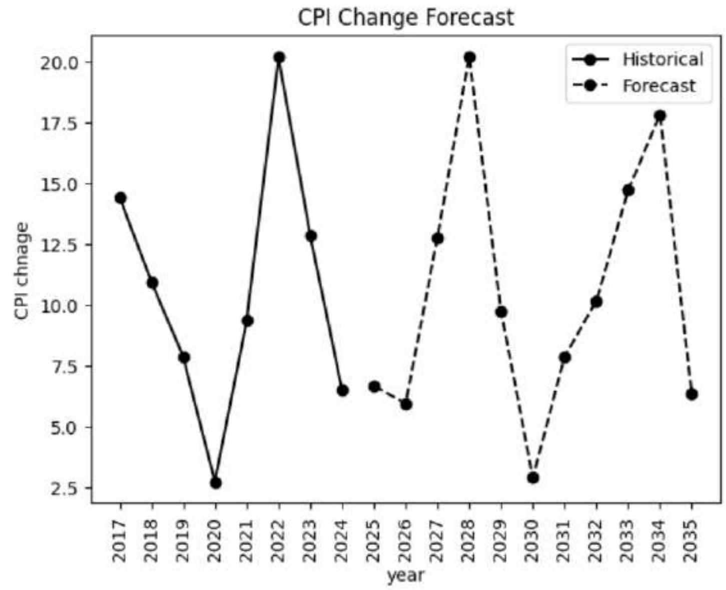

Figure 2.2 – Historical CPI change and CPI change forecast for 10 years ahead (2017-2035), %

Resource: authors' work from the Python code (ARIMA model) and based on the data from [16].

Table 2.4 Predicted CPI change for 2025–2035

Year	CPI change (Period average, Year-over-year percent change)				
2025	6,67%	**2030**	2,92%	**2033**	14,72%
2026	5,95%	**2031**	7,88%	**2034**	17,82%
2027	12,77%	**2032**	10,17%	**2035**	6,34%
2028	20,21%				
2029	9,74%				

Resource: authors' work from the Python code (ARIMA model) and based on the data from [16].

5. **Desired number of the workforce *(desired_employment)*.** The desired employment is calculated in the model as desired production divided by production efficiency. The initial number of the employees is 30 employees as we speak of a small enterprise in

Ukraine with a workforce under 50 employees according to the legislation [1; 2]. Although one of the goals of the simulation is to decrease the workforce involved in the process of production, the system has a limitation of a minimum of 20 employees so that no more than 35% of the workforce was cut.

6. **Desired production per year *(desired_production)*.** This number is calculated as the desired revenue divided by the unit price.
7. **Desired revenue per year *(desired_revenue)*.** This variable is a graphical one. The initial value is 6.000.000 UAH as it corresponds with the formula of the initial revenue (the initial number of produced goods multiplied by the unit price). And then there is a set of points of the automatic graphical logarithmic growth till the number of 11.100.000 UAH in 2035 (which is an 80% increase of the revenue in 10 years) (Fig. 2.3).

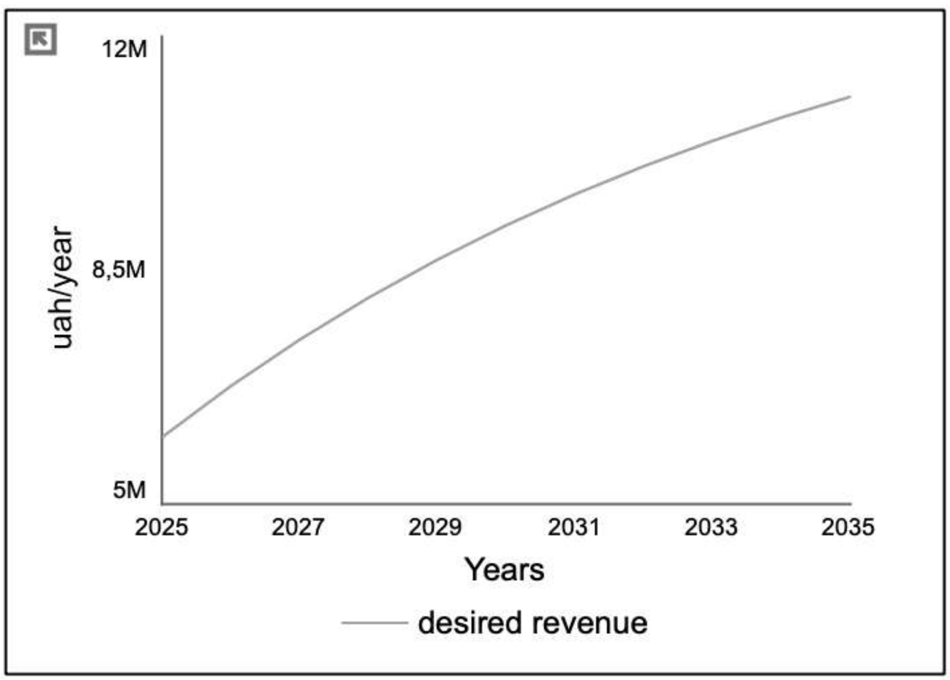

Figure 2.3 – Desired revenue (2025-2035), UAH/year

Resource: authors' work based on the model.

8. **The sum of investments made in the production efficiency *(sum_invested_in_production_efficiency).*** This is the money share of the profit that is allocated to implement the GLSS methodology into production. It is calculated as profit multiplied by the share that is decided to be allocated.
9. **The improvement effect of the investments made in production efficiency *(effect_of_investment_on_production_efficiency).*** This variable is needed to calculate how many units/person per year can be gained with the made investments. However, the formula also considers the diminishing effect of the investments which depends on the maximum production efficiency of a person per year, so as not to create an infinite improvement cycle. The variable is calculated as the sum invested in production efficiency multiplied by the efficiency gain per one invested UAH, then divided by the coefficient of the diminishing effect of the investments (1–production_effiency/max_production_efficiency).
10. **Maximum production efficiency *(max_production_efficiency).*** The value is 5.000 unit/person/year is calculated as a 5 times higher value than the initial production efficiency of the employees.
11. **Efficiency gain per one invested UAH *(efficiency_gain_per_uah).*** There is a lack of data on the effectiveness of investments in implementing the GLSS, although we know that the implementation requires considerable investments. The value of 0.0005 units/person/UAH implies that for each investment of 10,000 UAH, the production efficiency of the worker increases by 5 units.
12. **Fixed costs *(fixed_cost).*** This variable is fixed in the system. These are the costs that accompany the production process all the time. Initially in the model, they represent approximately 25% of the total costs, which is 1.000.000 UAH. The possible risks and economic influence are also taken into account so that there are two 15% increases twice a period every 4 years (in 2028 and 2032).
13. **Labour costs *(labour_cost).*** The labour costs per year are calculated by simply multiplying the number of employees by the salary.

14. **Total costs *(total_cost)*.** The total costs are the sum of the labour costs and the fixed ones.
15. **Revenue *(revenue)*.** The revenue is calculated as the number of produced goods multiplied by the unit price.
16. **Profit *(profit)*.** The profit is calculated by the simplified classical formula subtracting the costs from the revenue.
17. **Number of employees *(number_of_employees(t))*.** The number of employees is one of the variables that is observed and mentioned in the hypothesis. It is represented as a stock with the outflow of **employees no longer necessary for the processes *(workforce_reduction_rate)*** due to the improvement of production efficiency. The initial number of the employees is 30 speaking of a small enterprise in Ukraine.
18. **Production efficiency *(production_effiency(t))*.** The production efficiency is represented as a stock as well, it shows the the produced units per person per year. With the initial value of 1.000 pieces, it shall rise with the inflow of the **efficiency improvement rate *(efficiency_improvement_rate)*** which is calculated as the effect of investment on production efficiency divided by the adjustment time for efficiency improvement.
19. **Yearly salary *(salary(t))*.** This variable is calculated for the year 2025 based on the minimal monthly wage in Ukraine, which is 8.000 UAH, that is 96.000 UAH a year. Then the salary is yearly adjusted by the **salary gain *(salary_gain)*** due to inflation. The gain is calculated as the salary multiplied by the CPI change.

2.3 Used Methods and Analysis

When run, the simulation shows the dynamics through the next ten years (2025-2035) of the parameters and the variables described above. Therefore, running the model shows the visual representation of the effect of investments allocated in the improvement of production efficiency, i.e. the implementation of the GLSS.

However, since we do not have specific values for the profit percentage assigned to the production changes investments, the difference in this value may affect the essential effect of the implementation. As Foster (2007) has noticed in his work, the implementation of Six Sigma programs within cash-poor firms may be seen as a resource drain. Such companies may have a lack of time and resources to make all the necessary implementations and keep up with the changes and updates needed to maintain the new system [13].

To investigate whether the input variable of the sum of investments influences the target variables of the final financial result of the simulation, a sensitivity analysis has been conducted. The sensitivity analysis was conducted with a limited run number of 5 with random sampling (which also equals the number of samples for the input variable). The observable values for the share of the profit for investments were picked automatically from the range of [0; 1] with the incremental distribution, i.e. 0%, 25%, 50%, 75%, and 100%. Among the observable scenarios, the value of 40% was also added to compare the initial model with the various results from sensitivity analysis.

CHAPTER 3
THE EVALUATION OF THE SUCCESS OF THE IMPLEMENTATION OF THE METHODOLOGY IN THE MODEL

3.1 Results of the Model for Profit, Number of Employees, and Productivity

Generally, the model results highlight the assumptions that were stated before (Appendix B, Fig. B.2).

Over time there are a few key changes tendencies: (1) the production efficiency increases; hence the production and revenue also increase; (2) the number of employees decreases; (3) the costs increase; (4) the profit increases (Tab. 3.1). The ambiguous change is seen within the costs. Usually, the most common effect of the GLSS is a decrease in production costs; however, in the simulated system, the costs increase, both for fixed and labour costs. The increase in costs is explained by the influence of inflation on the salary and the predicted increases in fixed costs that accompany any company over time. This is the aspect of the model that may be considered for further development in research.

Table 3.1 The results of the simulation for Profit, Number of Employees, Production Efficiency, Salary, and Total Cost (2025-2035)

YEAR	PROFIT, uah/year	NUMBER OF EMPLOYEES, people	PRODUCTION EFFIENCY, (unit/people)/year	SALARY, uah/year	TOTAL COST, uah/year
2025	2 120 000	30	1 000	96 000	3 880 000
2026	2 693 559	30	1 126	102 253	4 074 037
2027	3 261 730	30	1 277	112 272	4 342 244
2028	3 379 037	29	1 444	132 383	4 985 323
2029	3 515 103	28	1 602	153 784	5 455 013
2030	3 963 353	27	1 766	163 838	5 572 519
2031	4 441 179	26	1 943	172 910	5 630 560
2032	4 368 808	25	2 125	189 233	6 162 633
2033	4 303 270	24	2 287	214 301	6 563 691

2034	3 897 530	23	2 432	252 144	7 250 326
2035	3 573 341	22	2 556	284 547	7 809 236

Resource: authors' work based on the model.

The profit has increased by almost 70% from 2.120.000 UAH in 2025 to 3.573.341 UAH in the final year of 2035, while the number of employees has dropped by approximately 27% from 30 to 22 people (with the available minimum of 20). The production efficiency indicators have almost tripled from the initial value of 1.000 units. The salary and total cost values have also risen, although it was not assumed in the hypothesis with the reliance on the literature observations. The salary has tripled, and the total cost has doubled, which may indicate that essentially the drastic effect of the inflation on the salary was slightly softened in the overall effect on the labour and therefore total costs. In the simulation of the Ukrainian enterprises, it is a good thing to count on the effect of the high inflation volatility for the next 10 years due to the uncertainty and the unpredictability of the economic and political situations. Let us look at the graphical representation of the results over time for the profit and the number of employees separately below and highlight some distinctive tendencies and observations.

The profit resembles the logarithmic growth that we've also set as a desired revenue, however, it also accounts for two 10% changes in the fixed costs in 2028 and 2032 that cause the one-time drops in the values (Fig. 3.1). Furthermore, there is a visible slight decrease in the profit after the year 2032. That may be the evidence of the adaptation of the system and the decrease of the improvement effect due to the diminishing effect of investments and the higher costs. It should be researched in the further works as well. In general, the increase of 70% in profit in 10 years due to the investments in production efficiency is a visible and noble result of the effect on the financials of the company.

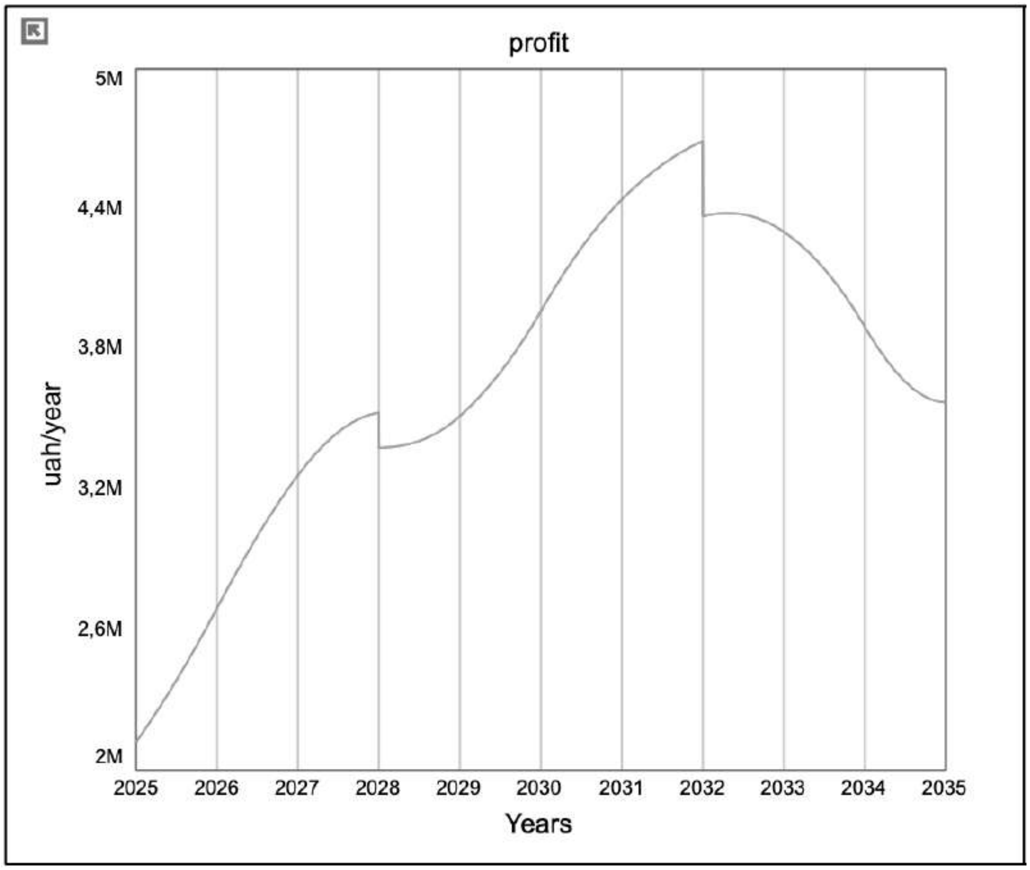

Figure 3.1 – Profit of the simulated enterprise (2025-2035), UAH/year

Resource: authors' work based on the model.

The number of employees has increased to 22 people (Fig. 3.2), therefore the basic rule of the optimization of the workforce due to the implementation of the GLSS is met in the model. It is important to mention that the decrease in labour may not be a bad thing from the point of view of the employees. In this simulation, for instance, one manufacturing process is observed, hence the decrease in the employees means that the employed units are used more efficiently, they can conduct more work and the ones who gain more knowledge and skills due to the learning programs, for example, may be transferred to different departments other than one single production. The main idea of the decrease in the number of employees is to relocate the resources in order to decrease the waste and number of defects.

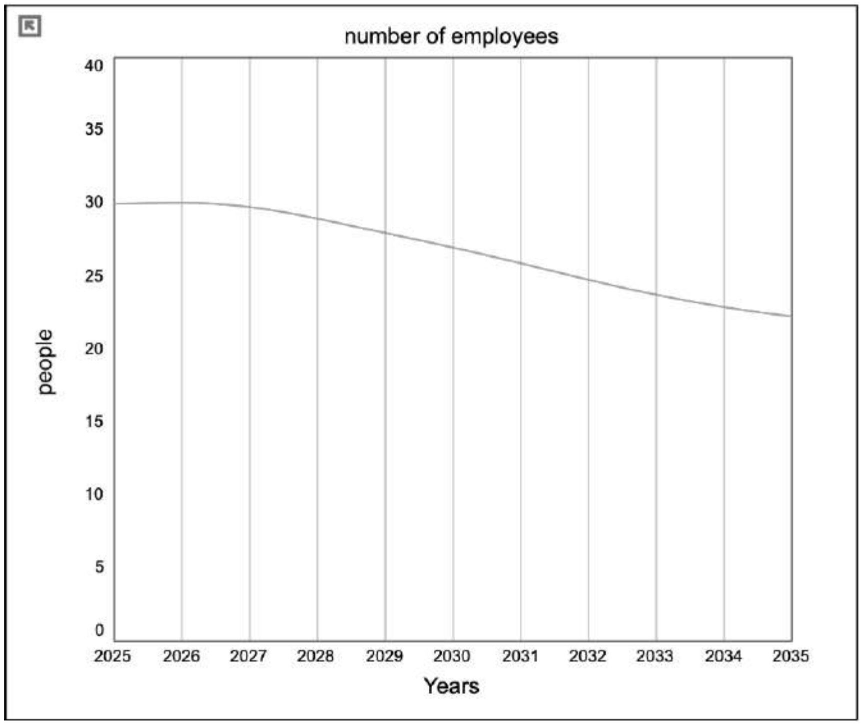

Figure 3.2 – The number of employees (2025-2035), people

Resource: authors' work based on the model.

3.2 Sensitivity Analysis of the Different Outcomes Due to Variable Shares of Profit for Investments

The results of the sensitivity analysis show the different behaviour and the result of the target variables (profit and number of employees) depending on the various values of the input variable of the share of the profit allocated for investments (Tab. 3.2).

Table 3.2 Final results of the variables within the sensitivity analysis (2035)

	% OF PROFIT FOR INVESTMENT	PROFIT (2035), UAH	NUMBER OF EMPLOYEES (2035), people
Run 1	0%	-6 024 475	54
Run 2	25%	342 446	32
Run 3	50%	5 155 653	20
Run 4	75%	9 872 094	20
Run 5	100%	12 015 918	20

Resource: authors' work based on the model with sensitivity analysis.

In the dynamical visual representation of the outcomes (Fig. 3.3), there is a distinct observation that the result for both variables (the profit and the number of employees) the value of 25% of the profit allocated to make the improvement changes has the negative impact on the profit and the positive on the workforce quantity. Having that in mind, there is a threshold of 25% in the model, below which the hypothesis and the goals are not met.

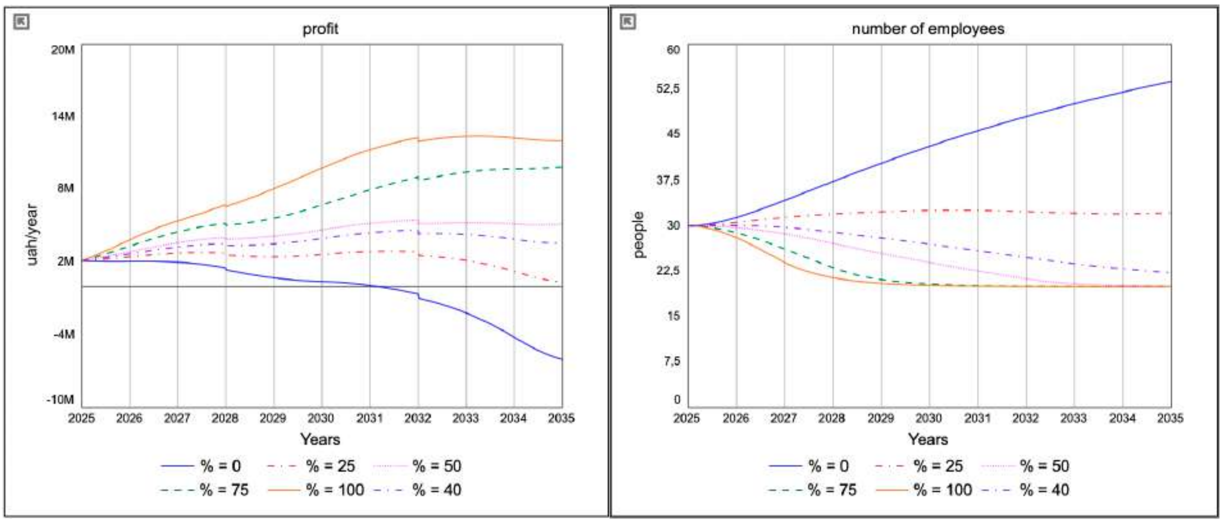

Figure 3.3 – The dynamics and the outcomes of the profit and the number of employees within the sensitivity analysis (2025-2035)

Resource: authors' work based on the model with sensitivity analysis.

3.3 Flaws of the Model and the Possibilities for Future Research

The results of the model logically resemble the real-world outcome, and the simulation considers different real-life effects (i.e. the diminishing effect of investments, the inflation influence, the limitation of the desired workforce etc.). However, the simulation is rather simplified for research reasons, whereas it could be improved within the next research projects.

Firstly, the calculation of the financial results in the model may be far more complex, including taxes, financial expenses, some other costs etc. All these factors could bring the model closer to the real-life financial pictures of the enterprises.

Secondly, as the paper is more focused on the financial side of the production, there is a lack of consideration of the production performance. For instance, the literature on the GLSS methodology suggests that there is a great impact on the production time, the amount of rework, the number of defects etc. This model on the other hand does not take into consideration these factors as separate variables. The addition of those factors and variables could improve the overall model performance in the context of the GLSS technology.

Thirdly, the environmental side of the methodology is not considered in the model. There may be further research dedicated to specifically the environmental impact of the implementation. Besides, the financial benefits of the "Green" upgrade (such as the incentives of lower taxation, higher investment attractiveness, lower waste management costs etc.) could be considered in the present but improved model. And finally, the model lacks the applied data currently. Possible future research may consider taking all the data from one enterprise to look at the outcomes that explain the real-life data.

Overall, the model confirms the main aspects of the hypotheses. Mainly the results show that the success of the profit increase is dependent on the value of the share of the profit, which was seen during the sensitivity analysis. The threshold of the successful investments was approximately 25% of the profit in this scenario. In the case of investments higher than the calculated percentage of the profit, there is a positive rise in the profit and a decline in the workforce amount. The ratio of the spent resources and the gain from the implementation is also considered to play a crucial role in the success of the process of change to meet the new Green Lean Six Sigma philosophy.

CONCLUSIONS

To conclude, based on the three hypotheses defined at the outset of this research, the simulation results provide a confirmation, with each hypothesis being either fully or partially supported. The first hypothesis stated that the effectiveness of implementing the GLSS methodology depends on the efficiency gain per unit of invested currency. While the model structure incorporated this relationship, the impact of varying efficiency gains was not comprehensively explored in this study and remains a subject for future sensitivity analysis and research.

The second hypothesis stated that the successful increase of profit due to GLSS implementation is highly dependent on the share of profit or available cash allocated for reinvestment. The results strongly support this, as sensitivity analysis demonstrated that the proportion of profit reinvested in production efficiency significantly influences both profit growth and workforce reduction. Notably, a 25% reinvestment threshold was identified as a critical value, beyond which the positive effects on profit and efficiency become much more pronounced.

The third hypothesis proposed that an optimal combination of investments in GLSS and an increased rate of production improvement would simultaneously increase profit and decrease the number of employees. The simulation confirmed this, showing that with optimal investment and improvement rates, profit can rise by nearly 70% over ten years while the workforce declines by 27%. This finding highlights the potential of GLSS methodologies to drive both financial and operational improvements when strategically implemented.

In summary, the study validates the importance of strategic reinvestment and efficiency gains in maximizing the benefits of GLSS, while also identifying areas such as the precise quantification of efficiency gain per investment for further investigation. These insights provide a valuable foundation for both academic research and practical application in organizational performance improvement.

In the future, the improvement of the model may include taxes, production performance indicators and detailed variables, ecological improvements and incentives, and surely testing the model with the data of some particular enterprise to observe the possible deviations from the hypotheses in the real life and adjust the model so it considers all the newly found specifics.

The Green Lean Six Sigma method is worth looking at for Ukrainian SMEs, although it is significantly important to evaluate the firm's cash flow, financial state, and possible implementation expenses to calculate the reasonability of the switch to the new adaptive management philosophy. The system dynamics model may be enhanced and used to predict the behaviour of the business within the transformation process and the years after that.

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Appendix A

Table A.1 The variables of the system dynamics model with the names, values and equations, initial properties and units

NAME	EQUATION/VALUE	PROPERTIES	UNITS
%_of_profit_for_ investment	0,4		Dimensionless
adjustment_time_for_ efficiency_improvement	3		year
adjustment_time_for_ workforce	1		year
cpi_change	GRAPH(TIME) Points: (2025,00, 6,67213156011), (2026,00, 5,94805403824), (2027,00, 12,7664107055), (2028,00, 20,2135367443), (2029,00, 9,73533736487), (2030,00, 2,91510115218), (2031,00, 7,87631627931), (2032,00, 10,1728265716), (2033,00, 14,7232219889), (2034,00, 17,8148868211), (2035,00, 6,34003701877)		1/year
desired_employment	MAX(desired_production/production_ effiency; 20)		people
desired_production	desired_revenue/unit_price		unit/year
desired_revenue	GRAPH(TIME) Points: (2025, 6000000), (2026, 6768000), (2027, 7462000), (2028, 8091000), (2029, 8660000), (2030, 9175000), (2031, 9640000), (2032, 10060000), (2033, 10440000), (2034, 10790000), (2035, 11100000)		uah/year
sum_invested_in_ production_efficiency	profit*"%_of_profit_for_investment"		uah/year
effect_of_investment_on_ production_efficiency	sum_invested_in_production_ efficiency*efficiency_gain_per_uah* (1-production_effiency/ max_production_efficiency)		(unit/people)/year
max_production_ efficiency	5000		unit/person/year
efficiency_gain_per_uah	0,0005		unit/person/uah

production	production_effiency*number_of_employees		unit/year
fixed_cost	1000000+STEP(150.000; 2028)+STEP(322.500; 2032)		uah/year
labour_cost	number_of_employees*salary		uah/year
total_cost	labour_cost+fixed_cost		uah/year
revenue	production*unit_price		uah/year
profit	revenue-total_cost		uah/year
unit_price	200		uah/unit
number_of_employees(t)	number_of_employees(t - dt) + (- workforce_reduction_rate) * dt	INIT number_of_employees = 30	people
workforce_reduction_rate	(number_of_employees-desired_employment)/adjustment_time_for_workforce		people/year
production_effiency(t)	production_effiency(t - dt) + (efficiency_improvement_rate) * dt	INIT production_effiency = 1000	(unit/people)/year
efficiency_improvement_rate	effect_of_investment_on_production_efficiency/adjustment_time_for_efficiency_improvement		(unit/people)/year/Years
salary(t)	salary(t - dt) + (salary_gain) * dt	INIT salary = 96000	uah/person/year
salary_gain	salary*cpi_change/100		uah/person/year/Years

Resource: authors' work based on the model.

Appendix B

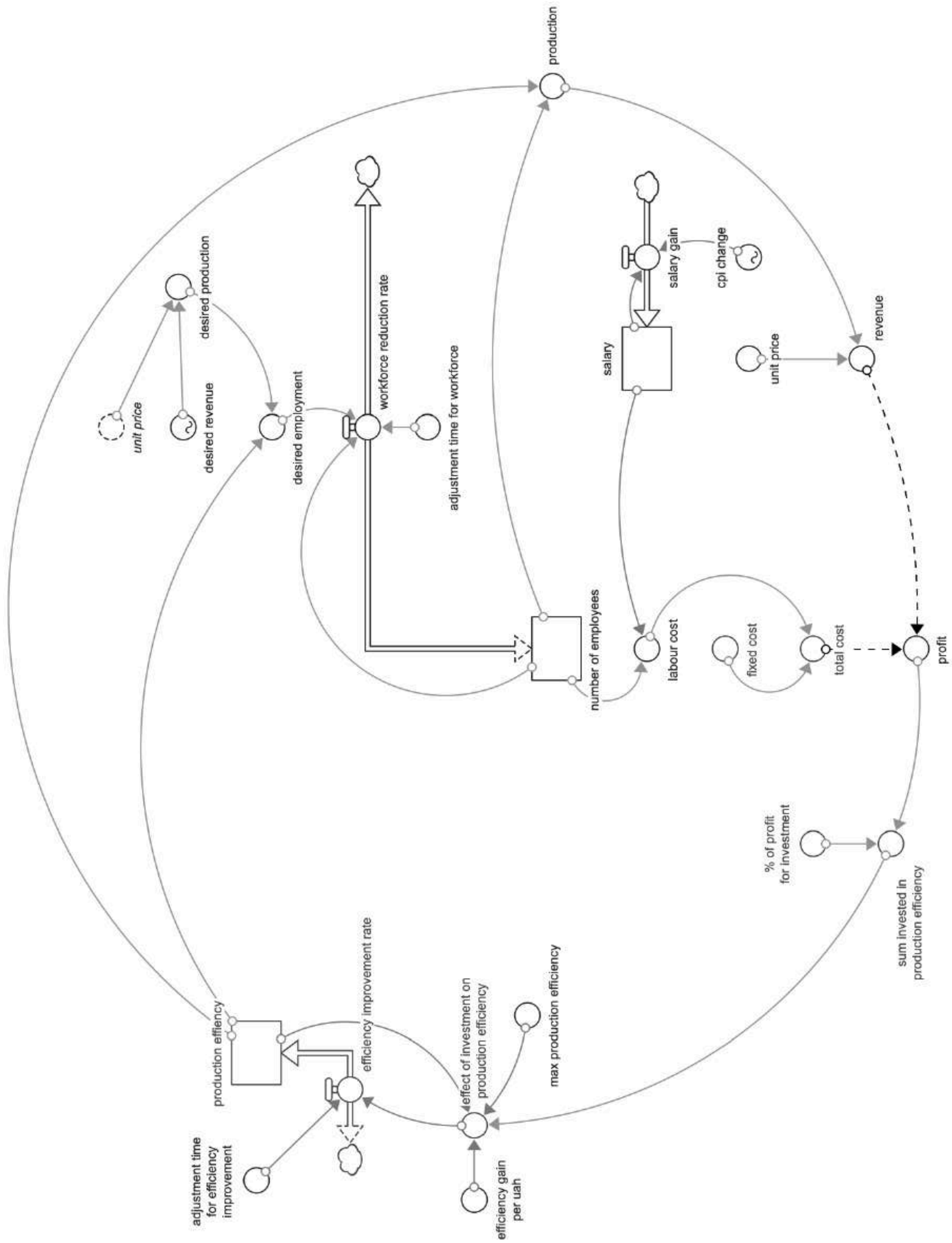

Figure B.1 – The system dynamics model of the influence of the GLSS implementation for a medium enterprise

Resource: authors' work.

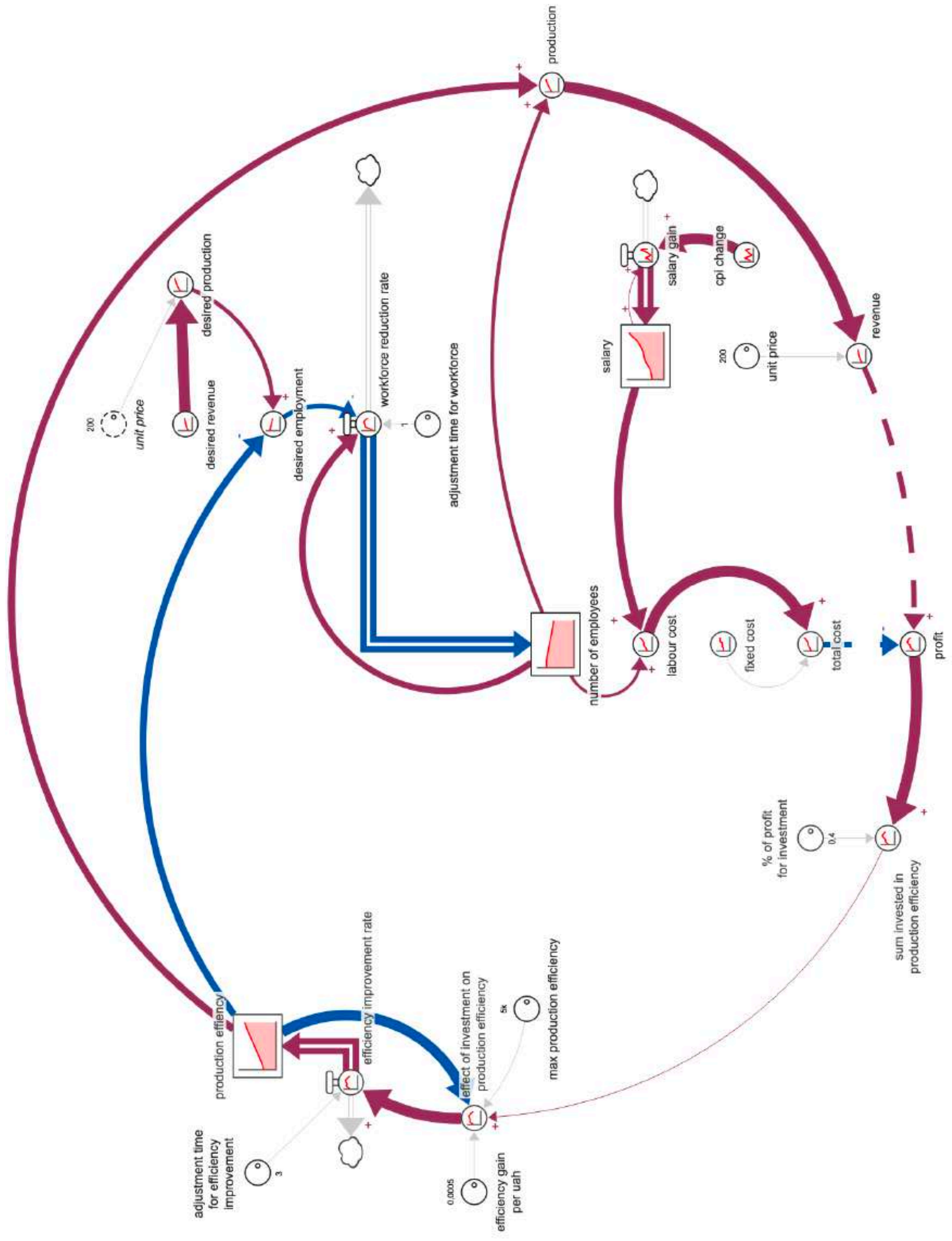

Figure B.2 – The results of the run system dynamics model of the influence of the GLSS implementation for a medium enterprise

Resource: authors' work.