

DEVELOPMENT OF A MODEL SUPPORTING THE ANALYSIS OF COSTS RELATED TO EQUIPMENT RELOCATION IN A MANUFACTURING FACILITY

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Abstract:

This paper presents a universal Excel-based cost estimation model for internal machinery relocation within manufacturing facilities. The objective of the study is to develop and validate a practical tool that enables accurate cost estimation and supports planning decisions in various industrial contexts. Although previous research has primarily focused on full-site relocations, internal repositioning of equipment has received limited academic attention despite its practical and financial relevance. The proposed model divides total relocation costs into three main components: equipment costs, labor costs and transport rental costs. To assist in decision-making and prioritization, the model applies the ABC classification method, grouping activities based on their financial impact. Selected principles of the OLESTR methodology, which integrates spatial and technological planning, are incorporated to enhance layout optimization. Developed in Microsoft Excel, the model was tested using a case study of a printing facility. Two layout variants were evaluated, each involving specific equipment relocation activities. Input parameters such as labor rates and equipment rental prices were defined as ranges to simulate real-world variability. The resulting variation in cost estimates across different simulation runs reflects the uncertain nature of industrial environments. The model offers a transparent, flexible and structured framework that supports industrial managers in evaluating layout alternatives, managing relocation budgets and minimizing disruption. Its adaptable design makes it applicable to a broad range of manufacturing settings and supports data-driven decision-making aimed at optimizing internal relocation processes and reducing associated costs.

Key words: relocation, machinery relocation, cost estimation model, factory layout, manufacturing facility, spatial planning, ABC classification, equipment repositioning

INTRODUCTION

The relocation of machinery within a manufacturing facility is often necessitated by both internal and external factors. Geopolitical disruptions such as wars, crises or changing environmental conditions, as well as the pursuit of resource optimization within international capital groups and the ongoing drive for production efficiency, all contribute to the need for facility reorganization. Repositioning of equipment can help firms adapt to unstable environments, optimize asset utilization or meet new technological requirements. While full-plant relocations to low-cost countries are well documented in the literature, internal relocations are frequently undertaken to improve space utilization, modernize workflows or integrate new machinery.

Although relocation decisions are widely recognized as complex and context dependent, the academic literature on the topic remains fragmented, often focusing narrowly on motivations, industry-specific cases or sustainability. Existing reviews typically draw on a limited number of

sources and do not fully explore the entire relocation process, from initial triggers to post-decision evaluation [1]. Machinery relocation within a manufacturing facility is a costly project undertaken by factory managers, typically driven by significant technical or operational needs. However, improving the layout of a facility can be a way to enhance productivity and reduce costs. Relocating the machinery is a process consisting of dismantling the machines and moving them to another location – at times to foreign facilities where production costs are lower [2, 3, 4]. However, the relocation process involves not only the physical movement of machinery but also the transfer of operational knowledge and rationale (know-how and know-why) to the new factory. Omitting this step might only bring losses in a form of downtimes, machines damage, reduced product quality, and other inefficiencies [5]. While full facility relocations are widely discussed in the literature [6, 7, 8], there is a growing interest for analyzing internal layout changes aimed at improving production flow and space utilization [9, 10]. Effective facility layout

design involves the identification of areas requiring improvement and can contribute to a reduction in a manufacturing plant's operational costs by up to 30%. The process of evaluating and selecting a layout variant is typically based on the analysis of the usefulness of redesign solutions and a qualitative assessment of costs, which entails significant time requirements and demands advanced methodological competencies from the planning team. Due to the lack of clear criteria for evaluating planning constraints, there is a risk of selecting solutions that do not fully meet the established project objectives. [11].

Consequently, the relocation of machines and tools is an essential component of the redesign process. Despite its significance, this area has received limited attention in previous research and requires further investigation. Manufacturing plants are designed to optimize production and minimize costs. Nevertheless, there are certain cases in which plant management may choose to replace outdated machines with new models, move the semi-finished and finished goods warehouse, renovate the plant by including new equipment, or simply shift tools to another section of the plant [12]. In such instances understanding the cost of the repositioning may be a key factor in the decision-making process. A tool that calculates the costs of adding or dismantling a machine, or moving an internal warehouse, would be especially useful when planning changes within a facility. To support prioritization of activities and enable better cost control, the study adopts the ABC methodology – to categorize relocation tasks based on their financial significance [13].

This study centers on calculating the costs of machinery repositioning using a case example of a printing plant. The aim is to develop a model that enables the calculation of equipment relocation costs, with particular emphasis on machinery, within a production environment. The work concentrates on identifying the key factors influencing relocation costs and analyzing the expenses associated with machinery transfers, with the goal of enabling cost reduction. This enables the determination of costs related to internal equipment repositioning, storage space transfer, as well as the installation of entirely new equipment. While the literature contains many examples of entire facility relocations, there are few cost-based approaches addressing machinery repositioning within a single plant. Such analysis would include labor costs, the cost of renting cranes or forklifts, permit costs, and related expenses. This paper aims to fill that gap by presenting a practical cost estimation framework.

LITERATURE REVIEW

Spatial planning of the manufacturing facility is crucial when it comes to the production optimization. A factory layout refers to the positioning of the machinery, tools and furnishings within a facility, and its preparation is a complex process that involves material flow analysis, defining relations between production cells, and more [14, 15]. During the layout planning process, five main procedures can be identified. The first is *activities*, which involves recognizing activity areas to create a base for the

layout – requiring input data about the planned production. The second procedure is *relationships*, which includes analyzing material flows and finding relations between activities. The next step is *space* – referring to physical and spatial requirements. The fourth procedure is *adjustments*, where the layout is modified, constrained by limitations, and compared to alternative arrangements. The final step is *evaluation*, during which the layout is assessed to find near-optimal solutions [16]. The layout of a manufacturing facility may be modified while the system remains in operation. Common reasons for re-layout include poor space utilization, excessive work-in-progress inventory, unnecessarily long transport routes, and even workplace accidents. [17, 18] Due to the constantly evolving manufacturing environments, the re-layout process is often iterative and continuous [19, 20].

The efficiency of a production facility is strongly influenced by its layout. Facility Layout Planning (FLP) focuses on arranging machines, workspaces, and other elements to meet operational goals while using space effectively, minimizing costs, and allowing for future layout changes – all with attention to safety [21]. Perhaps the most frequently applied method in this regard is Systematic Layout Planning (SLP). It gives us a step-by-step way for configuring the layout in terms of how the different activities relate one to another, the space the different activities occupy, and how the materials flow through the system [22]. At broader level, Strategic Facility Planning (SFP) helps companies tie facility layout decisions into the longer term, so the physical arrangement supports future growth and modifications. [23]. Lean manufacturing contributes to layout planning by promoting waste reduction, efficient material handling, and better space utilization. Its focus on streamlined processes and worker wellbeing leads to higher productivity and lower operating costs. A integration with SLP and simulation has been demonstrated as an ideal method for reducing transport distances and increasing the flexibility in the layout [24].

Given the importance and complexity of facility layout, various approaches have been developed to support production optimization efforts. Among the most commonly applied are the design of production-efficient layouts, the implementation of lean manufacturing principles, and the use of simulation techniques [25]. In terms of layout efficiency, certain objectives should be met. These include the minimization of material handling costs, production time, and equipment investment, as well as the maximization of productivity and resource utilization [26].

In most cases achieving the desired layout requires physical changes in the facility, including relocation of the existing machinery. Machinery relocation, as defined on industry websites, refers to the process of moving machines and equipment either within a single facility or from one site to another. Relocation consists of several stages, including planning, disassembly, transport preparation, transport and the equipment assembly at the final location. These steps require adequate documentation and thorough preparation. Once the idea of relocation has been verified, a relocation plan must be prepared. This

plan includes the sequence of operations, timeline of activities, required resources, responsibility areas, risk analysis, conditions of repositioning and essential information regarding machine startup. Each stage of relocation comprises multiple sub-tasks. To dismantle the machinery, workers must label parts and connections, disconnect utilities, disassemble the machine, and remove any non-transportable materials. After securing and labeling the elements those must be loaded onto the selected mode of transport, relocated, and reassembled at the new location. Before restarting production, additional steps must be completed – such as testing, finalizing documentation, and performing machine startup procedures [27]. Machinery relocation is required in several cases: factory modernization, establishment of a new plant, new machines integration, compliance with updated safety regulations, adaptation to new processes, or infrastructure constraints at a current location, among others. However, machinery relocation is viewed not only as a necessity resulting from changes in production, but also as a means of improving work quality [28].

While relocation is mostly described as a technical and logistical process, it obviously entails significant financial implications. The costs associated with machinery relocation such as transport, labor, and equipment rental can influence decisions related to spatial reorganization. The main objective of the relocation can be described as minimization of transport paths lengths, repositioning cost and the replanning implementation time [29]. In the methodological framework, the OLESTR approach plays a central role. This method, has been applied to both architectural and technological layout planning in production environments. According to this methodology, costs are categorized into distinct layers or groups enabling systematic segregation and clear visibility of financial impacts across different planning domains. The OLESTR framework thus offers an integrated perspective that supports detailed cost stratification and strategic, layered decision-making in facility planning [30].

Another concept supporting facility layout planning and relocation decision-making in terms of cost analysis is the application of the ABC classification method. ABC analysis is based on the Pareto principle (80/20 rule). It means that a small number of activities (20%) often account for the majority (80%) of total costs or impact [31, 32]. In the context of machinery relocation and spatial reorganization, this approach can be used to group planned activities according to their cost intensity. Class A would include high-cost and impact actions that should be prioritized or managed carefully; Class B covers moderate-cost tasks; and Class C includes the biggest number of activities, the ones that are the least costly, and can often be postponed.

ABC analysis is an well-established system used not merely for the inventory categorization but for prioritizing the broad array of cost in production and operations as well. Research demonstrated it effective in the identification of cost-weighty raw materials, customer-associated costs, and operating operations so that businesses could concentrate more on the highly impactful areas and

address less significant ones more effectively [33, 34]. Its use in previous researches for machinery relocating further validates the appropriateness for this application [35]. Applying ABC analysis, could simplify cost control and decision-making by focusing on the most financially significant operations. It also supports a more structured and economically justified approach to layout modifications.

Correspondingly, the Analytic Hierarchy Process (AHP) has been popular in use as a legitimate criterion for the choice of the optimum possible layouts, specifically for applications involving virtual reality simulation, where the arrangements could be judged instantly [36, 37]. For the printing facility under consideration two layout options had already been selected based on AHP. In this regard, the use of the ABC method is worth considering for the prioritization and ranking purposes of the investment cost of specific relocation actions, allowing for a more cost-conscious and strategy-focused implementation for the chosen layouts.

RESEARCH METHODS

The primary objective of this research was to develop a cost estimation model that supports decision-making during internal machinery relocation in manufacturing facilities. The model aims to enable transparent cost allocation, improve relocation planning accuracy, and minimize disruptions to production operations. The development of the proposed relocation cost estimation model was supported by elements of the OLESTR methodology, originally introduced for the spatial planning of industrial facilities. The OLESTR approach, based on a combination of technological and spatial planning, enabled the integration of real factory layout data with cost-related information such as dismantling, relocation, and reinstallation of equipment. Its application provided a structured basis for identifying and analyzing relocation scenarios within the printing plant [29]. The model supports optimization of spatial layout by allowing the user to test various configurations of equipment and infrastructure placement. It aims to improve functional efficiency while reducing relocation expenses.

The model was built in Microsoft Excel and consists of multiple interconnected worksheets. A dedicated interface sheet allows users to select machines and enter key inputs, while background sheets handle data storage and automatic cost calculations using built-in formulas. This structure ensures ease of use and supports fast, informed decision-making. The application of selected OLESTR principles further reinforced the practical value of the developed tool.

The proposed relocation cost estimation model focuses exclusively on internal machinery relocations within a single manufacturing facility. It does not cover international relocations, outsourcing processes, or moves involving infrastructure changes beyond the factory layout. In order to calculate the costs of individual relocation activities, several input values were defined. The hourly labor rate, the rental costs of forklifts and cranes, unit prices for racks

and freight elevators were identified [38]. These values were established based on extensive market research and industry consultations. In the Table 1 value ranges of input parameters are presented. The model draws a cost from the given range to complete calculations. The prices shown are based on Q1 2025 Polish market data. Considering price fluctuations and inflation, these inputs can be updated in the model as needed.

Table 1
Input parameters used in the relocation cost model – Cost Rates in EUR – Q1 2025

Cost description	Cost
Hourly rate	6.85 EUR
Crane rental cost per day	168.54-191.01 EUR
Electric forklift rental cost per day	103.37-107.87 EUR
Cost of 1 rack (6 PLT)	134.83-161.80 EUR
Low-capacity elevator cost	29 213.48-35 955.06 EUR
Medium-capacity elevator cost	49 412.36-53 932.58 EUR
High-capacity elevator cost	60 719.10-67 415.73 EUR
Cost of foundation per 1m ³	160.67-224.72 EUR

One of the objectives of this study is to reduce the total cost of machinery relocation by improving planning and by estimating the impact of the activities. This function can be defined as a sum of four components for each relocation activity.

$$RC = \sum_{i=1}^n (E_i + L_i + T_i + A_i) \rightarrow \min$$

where:

RC – total relocation cost

E_i – equipment cost: cost of purchasing new equipment for activity i : racks, elevators, fencing.

L_i – labor cost: the labor cost of activity i , calculated based on the hourly rate.

T_i – transport rental cost: the cost of renting transportation equipment (e.g., forklift or crane) for activity i

A_i – additional costs: any additional costs identified (e.g., cost of building permit) for activity i

n – number of relocation activities.

i – index of the specific activity.

Developing a model to calculate the cost of relocating machines required extensive research into current pricing and the procedures typically involved in such processes. Figure 1 illustrates the steps involved in creating this model.

The first step is identifying the machines that might be relocated within the facility. If there are any special requirements – such as obtaining a building permit – they need to be identified and included in the model, for example as additional waiting time and costs. Next, the number of workers involved in the project must be determined, the relocation time estimated, and the means of transporting the machine identified (e.g., whether a crane or a forklift is used).

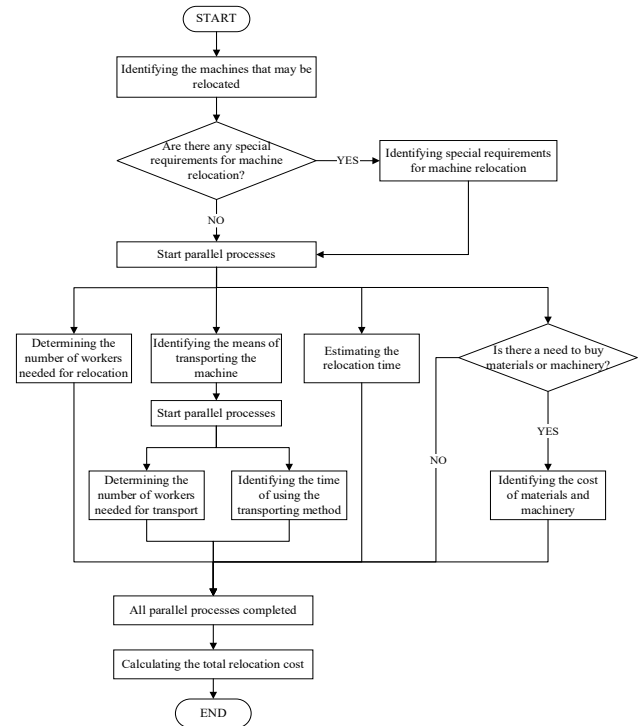


Fig. 1 Modeling steps in machine relocation cost estimation

At the same time, it is necessary to estimate potential costs of materials and additional machinery. Once the transport method is selected, the number of operators and the duration of use must be specified. When all these processes are completed, the total relocation cost can be calculated. This procedure must be repeated for each machine that may be relocated. Since the tool for calculating the total costs should be user-friendly, it is best to pre-calculate the possible relocation cost of each machine, allowing the user to simply specify whether they intend to relocate a particular machine.

It is worth mentioning that the model itself might not always produce identical results, even when the same machines are chosen to be relocated. The model is designed to reflect real-world conditions as accurately as possible – it means that for each machine, parameters such as relocation time, number of workers and others are defined as ranges instead of fixed values. During each cost calculation, the model randomly selects values from the given ranges. Ranges are included in the model because of the uncertainty and variability in machinery repositioning processes, where unforeseen factors can improve or worsen the process.

In this study, the layout of the printing plant and the machinery used within it were analyzed. The technological process diagram of manufacturing processes in the examined printing plant can be found on Figure 2.

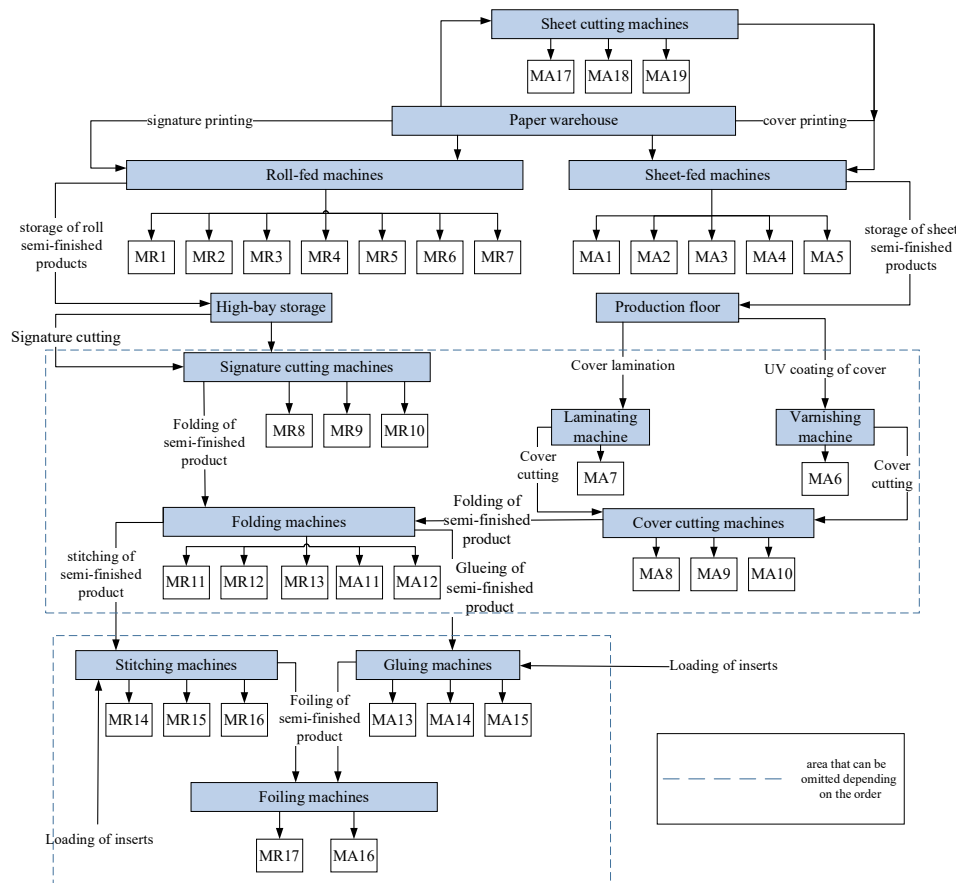


Fig. 2 Technological diagram of the production processes in the examined printing plant
Source: [29].

Based on that, the main groups of machines were identified, and each machine was assigned an identifier. These groups and their corresponding identifiers are summarized in Table 2.

Table 2

Groups of machines used in the facility and their identifiers

Machinery	Identifiers
Sheet cutting machines	MA17-MA19
Roll-fed machines	MR1-MR7
Sheet-fed machines	MA1-MA5
Signature cutting machines	MR8-MR10
Folding machines	MR11-MR13; MA11-MA12
Laminating machines	MA7
Varnishing machines	MA6
Cover cutting machines	MA8-MA10
Stitching machines	MR14-MR16
Gluing machines	MA13-MA15
Foiling machines	MA16; MR17
Other large-format machines (foundation required)	MW1-MW3

Source: own elaboration based on [29].

For the examined printing plant, layout was to be changed and two options were considered. The first option was Variant 1 (V1), the second one is Variant 2 (V2). In these two variants different machines are relocated. Each variant includes six phases.

In V1, in Phase 1, machine MR6 would be disassembled, and afterwards, 80 racks (800 PLT) would be installed in

its place. In Phase 2, the designation of the final products warehouse is changed to semi-finished products warehouse. In the Phase 3, plotters are relocated. The rack-handling machine is dismantled, as well as machines MA9 and MA10. 43 racks (258 PLT) and 32,5 meters of fencing are installed. The MA9 and MA10 are relocated and reinstalled. Machines MA6 (for UV varnishing) and MA7 (for cover lamination) are also installed. In Phase 4, 30 racks (180 PLT) would be disassembled, machines MR8-MR10 installed and around 20 meters of fencing added. In the 5th Phase, machines MR12-MR13 and MA11-MA12 are disassembled. Machine for rack-handling is installed and at the end of this phase, 65 meters of fencing is installed. The final phase – Phase 6 – involves disassembling of machines MR8-MR10 and installing machines MR12-MR13, MA11-MA12.

In the second variant (V2), the 1st Phase is exactly the same as in V1. In the Phase 2, 40 racks are dismantled, and machines MA9-MA10 are disassembled. Machines MA9-MA10 are later reinstalled in a different part of the facility. Afterwards, around 25 meters of fencing is installed. In Phase 3, plotters are relocated, and the rack-handling machine dismantled. Once completed, MA6-MA7 machines are installed. Phase 4, 5 and 6 are the same as in Variant 1. Since the changes in the factory for both variants have already been described, Figure 3 presents the layout for Variant 2 for reference only [29]. The detailed calculations and modifications are better captured in the cost relocation model, which is the main focus of the analysis.

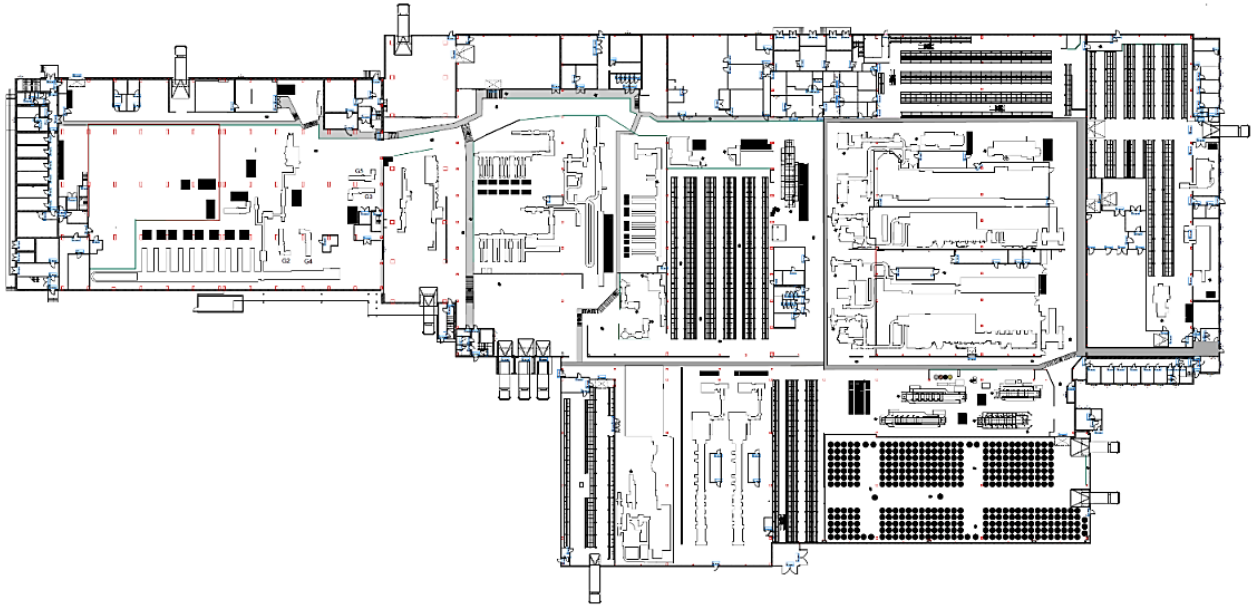


Fig. 3 Layout of the V2

Source: [29].

The model – a tool for calculating relocation costs – was developed based on the example of a printing plant; however, it can be adapted to the needs of other factories. The activities have been defined to serve as references for possible machine relocations. A total of 172 possible activities have been identified, including dismantling existing machinery, installing new machines, and even repurposing the warehouse. For the installation and dismantling of racks, intervals of every 10 racks were taken into consideration. The list of activities included in the model is presented in Table 3. The list was supplemented with additional possible activities that are not mentioned in V1 and V2 (such as elevator installation or installation of other large-sized machines).

Table 3

Activities defined in the model – potential machine relocations

Activities
Dismantling of machines MA9-MA12, MR6, MR8-MR10, MR 12-MR13
Dismantling of rack-handling machine
Installation of low, medium and high-capacity elevators
Installation of large-size machines MW1-MW3
Installation of machines MR1, MR8-MR10, MR12-MR13, MA6-MA7, MA9-MA12
Installation of rack-handling machine
Reclassification of finished goods to semi-finished goods warehouse
Relocation of plotters
Racks dismantled [0-200]
Racks installed [0-200]
Fencing installed [0-125m]
New foundations to be built [0-40m ²]

Source: own elaboration based on [29].

Each activity was carefully examined and multiple different scenarios were considered for each case. For racks installation, the user has the option to decide whether to purchase new racks and, if so, how many. An alternative

scenario is that the existing racks would be relocated – dismantled and reinstalled in a different part of the facility. That would make purchasing of new racks unnecessary. When it comes to fencing, discounts were incorporated into the model based on the total value of purchased panels. A 3% discount is applied to orders between approximately 450 EUR and 1.120 EUR, 5% for orders between 1.120 EUR and 2.020 EUR, 7% for orders between 2.020 EUR and 3.150 EUR, and 9% for orders exceeding 3.150 EUR. This approach in discounting is commonly used by retailers when selling goods in bulk [22]. For new foundations, both the waiting time for obtaining a construction permit and the permit cost itself were included in the model. In the case of large machines being repositioned, crane rental costs were accounted. For smaller machines, the use of an electrical forklift was assumed. The model would calculate the total usage time and include the corresponding rental cost in the final estimate. Each activity was classified into one of four categories – A, B, C, or D – using the ABC method. Each activity was associated with a specific cost, and the classification was based on the cumulative capital share. The capital share thresholds used for classifying activities into categories A, B, C, and D under the ABC method. In the A Class, 70% of cumulative share of costs can be found. Class B represents 18%; Class C covers 9%; and Class D accounts for the remaining 3% of the cumulative cost share. While class D represents only 3% of the cumulative costs share, the percentage of activities assigned to this class will be the highest of all classes.

RESEARCH RESULTS

Figure 4 presents the final view of the model's interface. It follows a color-coding scheme: darker green indicates user instructions, while light green cells are designated for user input. Although the interface is designed to be user-friendly, it is supported by complex background calculations. The interface consists of three main sections. In the

first section, user is required to answer two questions. The second section involves entering a numerical value by the user. Third – the largest section – the user selects the specific activities they intend to carry out within the manufacturing facility. The model view presents results for a printing plant in Poland; therefore, the model's visual outputs display prices in the Polish currency – zł. For better understanding, the values in the text and tables have been converted to EUR (July 2025 exchange rate). In the first input cell, the user must indicate if there is a need to

purchase racks. If the answer is YES – an additional question regarding the number of purchased racks will automatically appear on the screen. The user can also specify if they intend to rent a forklift – if selected, the associated rental cost will be added to the total, based on the rental duration calculated by the model.

Figure 5 presents an example of how these inputs are entered and illustrates user's interaction with the model for the first possible variant (V1) of the layout.

MODEL			
Relocation of the tools and machinery in a manufacturing facility - total cost			
Please answer below questions			Color code
Do you need to buy the racks?			Instruction
Is there a need to rent a forklift?			To be filled by user
Racks, fencing and foundations		Please provide a number	Cost [PLN]
Number of racks dismantled [0-200]			- zł 0
Number of racks installed [0-200]			- zł 0
Length of the installed fencing [m]			- zł 0
Area of the foundation [m2]			- zł Time included in the cost
Additional racks bought [not installed]		0	- zł 0
Activity	Please check if you will make this change	Cost [PLN]	Time [h]
Dismantling of machine MA10	<input type="checkbox"/>	- zł	0
Dismantling of machine MA11	<input type="checkbox"/>	- zł	0
Dismantling of machine MA12	<input type="checkbox"/>	- zł	0
Dismantling of machine MA9	<input type="checkbox"/>	- zł	0
Dismantling of machine MR10	<input type="checkbox"/>	- zł	0
Dismantling of machine MR12	<input type="checkbox"/>	- zł	0
Dismantling of machine MR13	<input type="checkbox"/>	- zł	0
Dismantling of machine MR6	<input type="checkbox"/>	- zł	0
Dismantling of machine MR8	<input type="checkbox"/>	- zł	0
Dismantling of machine MR9	<input type="checkbox"/>	- zł	0
Dismantling of rack-handling machine	<input type="checkbox"/>	- zł	0
Installation of a high-capacity freight elevator	<input type="checkbox"/>	- zł	0
Installation of a low-capacity freight elevator	<input type="checkbox"/>	- zł	0
Installation of a medium-capacity freight elevator	<input type="checkbox"/>	- zł	0
Installation of large-size machine MW1	<input type="checkbox"/>	- zł	0
Installation of large-size machine MW2	<input type="checkbox"/>	- zł	0
Installation of large-size machine MW3	<input type="checkbox"/>	- zł	0
Installation of machine MA10	<input type="checkbox"/>	- zł	0
Installation of machine MA11	<input type="checkbox"/>	- zł	0
Installation of machine MA12	<input type="checkbox"/>	- zł	0
Installation of machine MA6	<input type="checkbox"/>	- zł	0
Installation of machine MA7	<input type="checkbox"/>	- zł	0
Installation of machine MA9	<input type="checkbox"/>	- zł	0
Installation of machine MR1	<input type="checkbox"/>	- zł	0
Installation of machine MR10	<input type="checkbox"/>	- zł	0
Installation of machine MR12	<input type="checkbox"/>	- zł	0
Installation of machine MR13	<input type="checkbox"/>	- zł	0
Installation of machine MR8	<input type="checkbox"/>	- zł	0
Installation of machine MR9	<input type="checkbox"/>	- zł	0
Installation of rack-handling machine	<input type="checkbox"/>	- zł	0
Reclassification of finished goods to semi-finished goods warehouse	<input type="checkbox"/>	- zł	0
Relocation of plotters	<input type="checkbox"/>	- zł	0
Total time [days]			0
Forklift usage [days]			0
Cost of renting a forklift			- zł
TOTAL COST OF MACHINERY RELOCATION			- zł

Fig. 4 Relocation Cost Model – interface

Please answer below questions	
Do you need to buy the racks?	YES
How many racks do you need to buy?	93
Is there a need to rent a forklift?	YES
	YES
	NO

Fig. 5 Inputs entered by the user in the 1st Section of the interface

In the second section of the interface, a numerical value must be entered. The user defines how many racks within the warehouse are to be dismantled and how many racks are to be installed. Based on the needs of the printing plant, a constraint was applied – the user can only input a value between 0 and 200 for both questions, which range can be expanded if needed. The next question concerns installing fencing within the facility – mostly for safety reasons. In the model, the user can choose to install between 0 and 125 meters of fencing, with increments of 2.5 meters. The following question is about foundations – for some machines, new foundations must be added, and area of the new foundation is defined (range: 0-50 m²). In the column *Cost*, the cost of each operation is calculated. In the last row of Section 2, the cost of racks that were purchased but not installed is shown. Figure 6 presents data input for this section for considered V1 variant of the layout.

The final – third – section of the interface allows the user to define which activities will be included in the relocation

process. The *Cost* and *Time* columns display the calculated values for each selected activity. Activities are divided into three groups: machine dismantling, machine installation and other tasks. The list consists of a total of 32 actions that can be selected. Figure 7 presents an example of activities selected by the user in the last section, based on the V1 variant of layout.

When the sections are completed with data provided by the user, the total relocation time – in days – is calculated and displayed below the sections. This value includes both the duration of relocation processes as well as the potential waiting time (an additional waiting time is added if an activity requiring a permit is selected). Below this, the total time of a forklift usage is calculated. Finally, the total cost of the machinery relocation is displayed on the screen. Table 4 presents the overall relocation cost for V1 replanning variant based on the options selected in Figures 5, 6 and 7.

Racks, fencing and foundations	Please provide a number	Cost [PLN]	Time [h]
Number of racks dismantled [0-200]	30	610,00 zł	5
Number of racks installed [0-200]	123	85 071,50 zł	11
Length of the installed fencing [m]	117,5	13 907,80 zł	9
Area of the foundation [m ²]	97,5 100,0 102,5 105,0 107,5 110,0 112,5 115,0 117,5 120,0 122,5 125,0	- zł	Time included in the cost
Additional racks bought [not installed]		- zł	0

Fig. 6 Inputs entered by the user in the 2nd Section of the interface

Activity	Please check if you will make this change	Cost [PLN]	Time [h]
Dismantling of machine MA10	<input checked="" type="checkbox"/>	732,00 zł	8
Dismantling of machine MA11	<input checked="" type="checkbox"/>	1 098,00 zł	9
Dismantling of machine MA12	<input checked="" type="checkbox"/>	854,00 zł	7
Dismantling of machine MA9	<input checked="" type="checkbox"/>	732,00 zł	8
Dismantling of machine MR10	<input checked="" type="checkbox"/>	24 400,00 zł	50
Dismantling of machine MR12	<input checked="" type="checkbox"/>	976,00 zł	8
Dismantling of machine MR13	<input checked="" type="checkbox"/>	854,00 zł	7
Dismantling of machine MR6	<input checked="" type="checkbox"/>	95 716,50 zł	223
Dismantling of machine MR8	<input checked="" type="checkbox"/>	24 888,00 zł	51
Dismantling of machine MR9	<input checked="" type="checkbox"/>	25 864,00 zł	53
Dismantling of rack-handling machine	<input checked="" type="checkbox"/>	640,50 zł	7
Installation of a high-capacity freight elevator	<input type="checkbox"/>	- zł	0
Installation of a low-capacity freight elevator	<input type="checkbox"/>	- zł	0
Installation of a medium-capacity freight elevator	<input type="checkbox"/>	- zł	0
Installation of large-size machine MW1	<input type="checkbox"/>	- zł	0
Installation of large-size machine MW2	<input type="checkbox"/>	- zł	0
Installation of large-size machine MW3	<input type="checkbox"/>	- zł	0
Installation of machine MA10	<input checked="" type="checkbox"/>	1 342,00 zł	11
Installation of machine MA11	<input checked="" type="checkbox"/>	3 111,00 zł	17
Installation of machine MA12	<input checked="" type="checkbox"/>	2 745,00 zł	15
Installation of machine MA6	<input checked="" type="checkbox"/>	1 952,00 zł	16
Installation of machine MA7	<input checked="" type="checkbox"/>	1 952,00 zł	16
Installation of machine MA9	<input checked="" type="checkbox"/>	1 342,00 zł	11
Installation of machine MR1	<input type="checkbox"/>	- zł	0
Installation of machine MR10	<input checked="" type="checkbox"/>	10 370,00 zł	34
Installation of machine MR12	<input checked="" type="checkbox"/>	2 745,00 zł	15
Installation of machine MR13	<input checked="" type="checkbox"/>	3 111,00 zł	17
Installation of machine MR8	<input checked="" type="checkbox"/>	13 084,50 zł	39
Installation of machine MR9	<input checked="" type="checkbox"/>	11 590,00 zł	38
Installation of rack-handling machine	<input checked="" type="checkbox"/>	732,00 zł	8
Reclassification of finished goods to semi-finished goods warehouse	<input checked="" type="checkbox"/>	- zł	0
Relocation of plotters	<input checked="" type="checkbox"/>	122,00 zł	2

Fig. 7 Inputs entered by the user in the 3rd Section of the interface

Table 4
Total relocation cost for options selected in Figure 3, 4 and 5 – V1 total cost

Parameter	Value
Total time [days]	184
Forklift usage [days]	38
Cost of renting a forklift	3 902.47 EUR
Total cost of machinery relocation	76 191.63 EUR

This model enables quick calculation of the total cost and duration of the relocation process, with all cost components clearly stated. The total cost may vary even for the identical operations, as the model is built on possible ranges of time and unit costs for each activity. For the input values presented in Figure 3, 4 and 5, the model was run five times, and the results are presented in Table 5.

Table 5
Variability of cost estimates for identical input parameters – V1

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Total time [days]	184	186	186	187	183
Total cost [EUR]	76 194.83	76 847.08	76 636.41	75 477.25	74 827.07

Source: own elaboration, based on inputs presented in Figure 3, 4 and 5.

The highest estimated total cost among these five runs was 76 847.08 EUR, while the lowest was 74 827.07 EUR. This variation is a consequence of the model’s design which takes into account possible differences in tasks durations, prices fluctuations and other unforeseen factors that may arise during the relocation process.

Next step was to calculate the total relocation cost for Variant 2. Table 6 shows five results obtained from five runs of the model for Variant 2, using identical input parameters.

Table 6
Variability of cost estimates for identical input parameters – V2

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Total time [days]	184	184	183	184	183
Total cost [EUR]	87 184.47	84 756.26	87 420.32	84 419.76	86 715.76

Source: own elaboration, based on inputs for V2.

The highest result recorded was 87 420.32 EUR, while the lowest was 84 419.76 EUR. Figure 8 presents the input options selected in the model to represent the relocation changes in Variant 2. Among the analyzed variants, Variant 2 resulted in higher overall costs, as reflected in the model outcomes.

Please answer below questions			
Do you need to buy the racks?		YES	
How many racks do you need to buy?		130	
Is there a need to rent a forklift?		YES	
Racks, fencing and foundations			
	Please provide a number	Cost [PLN]	Time [h]
Number of racks dismantled [0-200]	70	762,50 zł	5
Number of racks installed [0-200]	200	130 602,50 zł	15
Length of the installed fencing [m]	110	13 228,37 zł	8
Area of the foundation [m ²]		- zł	Time included in the cost
Additional racks bought [not installed]	0	- zł	0
Activity			
	Please check if you will make this change	Cost [PLN]	Time [h]
Dismantling of machine MA10	<input checked="" type="checkbox"/>	823,50 zł	9
Dismantling of machine MA11	<input checked="" type="checkbox"/>	854,00 zł	7
Dismantling of machine MA12	<input checked="" type="checkbox"/>	854,00 zł	7
Dismantling of machine MA9	<input checked="" type="checkbox"/>	732,00 zł	8
Dismantling of machine MR10	<input checked="" type="checkbox"/>	24 400,00 zł	50
Dismantling of machine MR12	<input checked="" type="checkbox"/>	854,00 zł	7
Dismantling of machine MR13	<input checked="" type="checkbox"/>	1 098,00 zł	9
Dismantling of machine MR6	<input checked="" type="checkbox"/>	85 259,00 zł	231
Dismantling of machine MR8	<input checked="" type="checkbox"/>	24 766,00 zł	58
Dismantling of machine MR9	<input checked="" type="checkbox"/>	25 620,00 zł	56
Dismantling of rack-handling machine	<input checked="" type="checkbox"/>	732,00 zł	8
Installation of a high-capacity freight elevator	<input type="checkbox"/>	- zł	0
Installation of a low-capacity freight elevator	<input type="checkbox"/>	- zł	0
Installation of a medium-capacity freight elevator	<input type="checkbox"/>	- zł	0
Installation of large-size machine MW1	<input type="checkbox"/>	- zł	0
Installation of large-size machine MW2	<input type="checkbox"/>	- zł	0
Installation of large-size machine MW3	<input type="checkbox"/>	- zł	0
Installation of machine MA10	<input checked="" type="checkbox"/>	1 342,00 zł	11
Installation of machine MA11	<input checked="" type="checkbox"/>	3 111,00 zł	17
Installation of machine MA12	<input type="checkbox"/>	- zł	0
Installation of machine MA6	<input checked="" type="checkbox"/>	1 952,00 zł	16
Installation of machine MA7	<input checked="" type="checkbox"/>	1 830,00 zł	15
Installation of machine MA9	<input checked="" type="checkbox"/>	1 464,00 zł	12
Installation of machine MR1	<input type="checkbox"/>	- zł	0
Installation of machine MR10	<input checked="" type="checkbox"/>	9 882,00 zł	36
Installation of machine MR12	<input checked="" type="checkbox"/>	3 111,00 zł	17
Installation of machine MR13	<input checked="" type="checkbox"/>	3 111,00 zł	17
Installation of machine MR8	<input checked="" type="checkbox"/>	13 420,00 zł	40
Installation of machine MR9	<input checked="" type="checkbox"/>	10 675,00 zł	35
Installation of rack-handling machine	<input checked="" type="checkbox"/>	823,50 zł	9
Reclassification of finished goods to semi-finished goods warehouse	<input type="checkbox"/>	- zł	0
Relocation of plotters	<input checked="" type="checkbox"/>	183,00 zł	3
TOTAL COST OF MACHINERY RELOCATION			377 690,37 zł

Fig. 8 Model results for the 2nd variant of layout (V2)

The ABC method allowed to classify each activity into a specific category. That helped in identification of the most critical and cost-intensive tasks, classified as Class A. Out of 172 activities, 19,2% were categorized as Class A. The largest percentage of activities falls into class D (37,8%), which is a typical outcome in ABC analysis, as class D represents only 3% of total capital share, despite including the highest number of activities. Class A includes all activities involving large machinery such as installation of elevators, dismantling and installation of large-sized machines and construction of foundations for areas exceeding 28 m². Since the cost of each activity can slightly change in each model run (as the model draws some input parameters from predefined value ranges), the ABC classification may change as well. Activities positioned near the boundaries between categories may shift from one class to another depending on the run. Table 7 presents a summary of the capital share for each class, along with the percentage of activities included in the corresponding category, based on three separate executions of the model.

Table 7
Capital share thresholds and the percentage of activities in A, B, C and D categories

Class	Capital share	Percentage of activities – 1 st run	Percentage of activities – 2 nd run	Percentage of activities – 3 rd run
A	70.00%	19.19%	19.19%	19.77%
B	18.00%	20.35%	19.77%	20.35%
C	9.00%	22.67%	23.26%	23.26%
D	3.00%	37.79%	37.79%	36.63%

Importantly, the ABC method allowed for the classification of the similar activities into different categories, depending on the number of relocated equipment items. Such comparison can be found in Table 8. This highlights the effectiveness of this method in capturing both the cost and scale of operations.

Table 8
ABC classification of activities based on relocated equipment quantity and scope

Class	Foundation areas	Racks dismantled	Racks installed	Fencing installation
A	29-50 m ²			
B	12-28 m ²			85-125 m
C	4-11 m ²		180-200	22.5-82.5 m
D	1-3 m ²	1-200	1-179	2.5-20 m

DISCUSSION OF THE RESULTS

The integration of ABC classification with the OLESTR methodology was proposed for the first time in this study, enabling a detailed, structured and practical representation of the internal machine relocation costs within a factory. The proposed model not only estimates the costs of individual activities but also provides a clear classification of which actions consume the most financial resources. This way, this model is a direct contribution in the investment plan – an area where transparency and prioritization in expenditures is most needed. The results obtained from multiple model iterations demonstrate that final cost

outputs vary even with the same input selections. This variance reflects the model's design, which incorporates ranges for inputs such as labor duration or rental prices. As a result, users can better account for uncertainty within relocation instances and plan for budget contingencies. In practice, this ability increases the model's application in industrial decision-making and plausible financial forecasting. ABC analysis, applied within the model, enabled the categorization of 172 identified activities into strategic cost groups. For example, class A activities – with 70% share of total capital – mostly comprise the high-impact activities such as installing an elevator, shifting heavy machinery, and constructing machine foundations. This classification makes it possible to focus the attention of the managers on the most capital-consuming actions. The Pareto-based strategy underlies the efficiency not only by revealing where the majority of costs are concentrated, but also by highlighting less critical activities that can be streamlined or postponed. This is most vital under the context of investment decisions. The developed tool allows managers to evaluate various relocation options and understand how their decisions affect overall costs. Since facility layout changes are often part of broader investment plans, the ability to forecast relocation costs is essential. The model is thus utilized as a decision-support tool at the preliminary planning period – where approximate estimates for the purpose of capital allocation are needed.

Although the model was created and tested using data from a single printing facility, the model structure allows for easy extension to other production sites. However, it should be emphasized that each factory operates under unique spatial, technological, and organizational constraints. Therefore, future research should extend this approach to different types of industrial plants, including those with different production flows or higher automation levels.

CONCLUSIONS

The conclusions of this study highlight the importance of including machinery relocation cost when replanning the layout of the manufacturing facility. This analysis shows that the developed relocation cost model can be effectively used to calculate planned repositioning activities in the facility. It allows fast and accurate cost estimation, as well as calculation of the expected relocation time, which supports better planning and decision-making. The model was verified and tested, and after initial runs, additional activities (not planned in V1 or V2) were added, like large machinery or elevator installation. These were validated using the ABC methodology, classifying these additional activities to A class. Including such activities broadens both the applicability of the model across different types of manufacturing facilities and the range of scenarios it can support during layout replanning.

Variability in the results allows for flexible and realistic budget planning, with the highest estimated costs giving a possible buffer in financial forecasting. The model enables comparison of different layout scenarios, including

ones which may involve higher costs but align better with operational constraints or long-term spatial plans. In such cases, it offers cost clarity and supports well-balanced decision-making based on economic as well as logistic factors. Notably, the model is highly practically relevant, since it can be applied in actual industrial operations to assist with initial-stage investment planning. In providing initial cost estimates, it enables companies to evaluate financial viability and anticipate the logistical impact of layout modifications prior to implementation. The model's adaptability and ease of use make it applicable to both large-scale relocations and smaller-scale layout adjustments.

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