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Utility of Designing Intelligent Algorithms to Streamline E-Commerce Operations and Construction Costs Estimates by Applying Principles of Sharing Economy: Coestim

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Abstract: Through technological advances and the use of online platforms, the perfect environment was created to revolutionize the field of construction. Over the years, this field has faced difficulties in optimizing resources and reducing time and costs, but the maneuverability and operability of the project delivery process, of which are crucial elements. The economic and industrial crises of the last decade have exerted enormous pressure in the process of maximizing quality, being necessary models and algorithms to obtain an ideal recipe. This article presents the first proposal of a metaheuristic algorithm capable of optimizing the most important objectives of service providers in the time-quality-cost ratio without reaching a compromise disadvantaging one of the basic characteristics. The model is applied in the generation of estimates, revolutionizing the field of construction, based on the cost-estimate motto that leads to the abbreviation Coestim.

Keywords: data fusion; big data; IoT; e-commerce; time-cost-quality; multi-objective optimization; web application

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1. Introduction

The continuous progress in the field of technology, IoT, Artificial Intelligence, but also the Internet, forces companies to address externalization of the e-commerce, and orders but also increase the number of customers. The difficult period of 2019–2020 in the full pandemic of COVID-19 showed that there are extremely many unimplemented elements in the field of electronic commerce [1]. Most online merchants using e-commerce platforms have faced extremely many problems. We can say that the most eloquent were those related to stocks, invoicing, delivery, and generation of AWB, all these elements overloaded the plat-forms and sometimes interrupted their activity. It is imperative to have a dedicated e-shopping platform assistant to recommend and manage existing stocks at the best prices. The standardization of electronic commerce is an extremely little researched direction because most of the personnel specialized in this direction work in production without coming into direct contact with the research [2]. The utility of a customized system that processes every search or order through an advanced business intelligence method manages to verticalize the data extraction process and at the same time helps both the e-store chain and the end customer. The existence of solutions such as traditional collaborative filtering (CF) algorithms or those solutions that import from billing applications has a major disadvantage in the case of extremely bulky processing [3]. The most important aspect of e-commerce is related to the rendering of information in real-time, which we can not achieve through collaborative filtering algorithms, they can not properly analyze existing stocks compared to those on the online market, but especially may not analyze existing prices to adjust the costs of own products to those in the market.

The analysis of 2021 highlights extremely many disturbances, they have largely affected all industrial areas, greatly degrading the economic situations of many countries. An extremely important field that suffers is that of construction, which is discovered by the lack of maturity in the digital field, and this was also observed in 2022 when the armed conflict between Russia and Ukraine escalated and an economic crisis is making its presence felt. According to the analysis, over 75% of those working in the field of construction have expressed interest in investing in digital transformation following the confrontations in the first part of the year. The digitization of companies and manufacturers of construction materials or service providers leads them to m11assive investments. We can say that this result also comes from customer demand, but also based on technological advancement reaching Industry 4.0 which is in a continuous expansion towards Industry 5.0 [4,5].

The massive demand from customers in the background of social instability, but also in terms of economic issues, pushes the whole society to e-commerce, from this equation construction materials companies are most targeted in terms of the fact that they are the least digitized. Most customers come from urban areas that are moving to rural locations where they can outline a new environment and at the same time a new lifestyle for which they need construction materials, and tools, but also service providers. The analysis carried out in 2019 before the COVID-19 pandemic crisis and the war in Ukraine, reported the following aspects, related in Figure 1:

Figure 1. Analysis of the construction situation in 2019.

Why should the field of construction and construction materials focus on e-commerce? According to forecasts, this sector can have a global market value of over one trillion dollars by 2030. We can say that an online sales channel can significantly adjust the profit, facilitating further developments in a way as graceful as possible. Through an e-commerce platform that is based on the customer's needs, a large part of the existing customers on the market can be captured, only based on the criticisms exposed by them in the existing interactions. The demand for e-commerce in the industrial field and especially in the construction field is much higher than in the inter-industrial area, which shows that over 85% of companies in the industry that in the near future will sell 100% of their products and an online environment. We can say that an increase in efficiency through intelligent automation and e-commerce is within the reach of anyone in the commerce industry [6,7].

We can say that in addition to the uncertainty created around the market and the economy, the most important thing in a company is data management, especially if it is conducted in a faulty and inefficient way. This aspect can outline a real threat to the success of transforming the company into a digital and fully optimized one. In a world where purchasing power is directly influenced by the evolution of B2B, we must be careful how we present the data so as not to be misinterpreted. The optimization of platforms and the creation of progressive algorithms that use all possible resources, positively influence the relationships with suppliers, but also with customers. As the issues have been removed from this equation, you can continue the technology process, whether you are using SAP or Microsoft Dynamics ERP solutions [8,9].

According to previous presentations, the fourth ongoing industrial revolution has managed to change the perception of daily activities and digitalize them as much as possible. We can say that the process of continuous digitization in our society has allowed the generation of extremely large volumes of data. Therefore, global internet traffic is the highest in the last 30 years, and the trend is still on the rise. According to CISCO, we note that the annual network traffic for 2020 was around 2.4 Zettabytes or more precisely over 61,000 GB per second. The forecast for 2022 that comes from the World Bank is that it will reach the threshold of 150,000 GB per second [10]. Through this explosion of new data and extremely high traffic, new technologies and algorithms have been developed dedicated to the processing dedicated to extremely large data, some of the solutions are limited to the creation of typical relational databases. We can say that the efficient handling of large quantities of data is extremely important, even crucial because in the case of e-commerce platforms there are products or services that derive from a basic product or product ID. The duplication of a product can cause problems with machine learning (ML) or even deep learning (DL) classifiers. In the case of e-commerce platforms, these systems, process data structures and massive sets of information, and merger processes can increase performance in the final process. Therefore, e-commerce systems can also involve heterogeneous data sources, sensors, GPS tracking systems, order processing with trackers, or digital sources, which are characterized by multimedia content. The approaches presented can be summarized as a standard flow of the processes or methodology presented in the context of data fusion in an e-commerce system in Figure 2 [11].

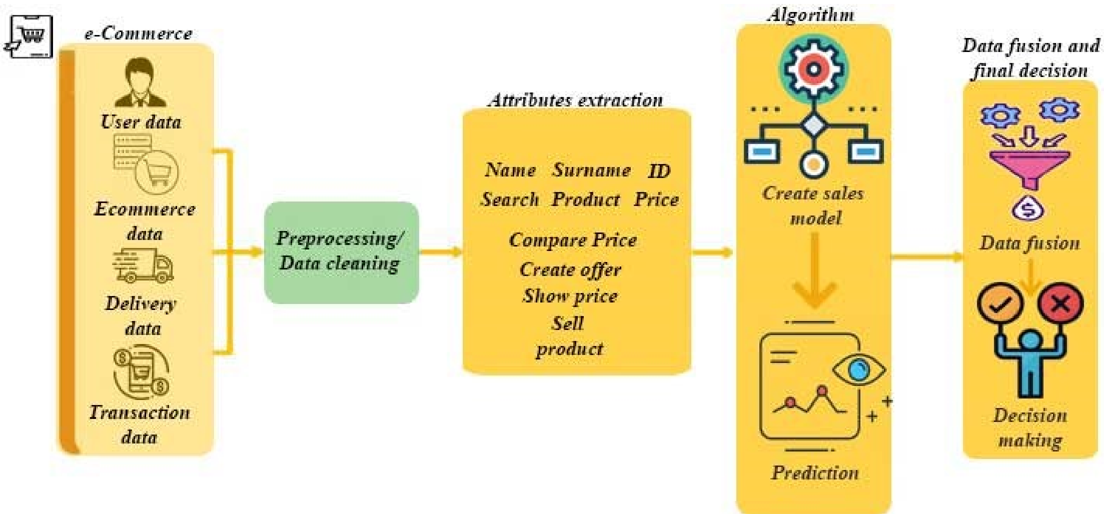

Figure 2. Process flow for data fusion in an e-commerce system.

Study and Analysis of Algorithms Dedicated to Cost Estimation

The efforts of the communities in the development of e-commerce platforms have been channeled towards the implementation of new modules based on customer recommendations. Whether we are talking about, Amazon, eBay, Alibaba, Netflix, but also many others, make this field an extremely versatile one that pushes the user from behind in his browsing process. We can say that Bonhard and Sasse studied the influences of the social environment on users in terms of recommendations, accepting those recommendations based on their searches. Recent studies have been conducted by Sinha and Swearingen, experimenting with online referral systems based on the recommendations, but also through online advertising, which led to an extremely important conclusion, users' appetite for shopping in the recommended niche was opened. Perhaps some of the most important achievements come from Nguyen and his collaborators, creating a non-linear GFPM probability algorithm to obtain a recommendation point. This point is supported by Gaussian progress, based only on information from the feedback, but in turn, it can generate recommendations. An extensive study was conducted by Hyang and Benyoucef, reviewing all relevant research found in the e-commerce literature, illustrating the concept of social commerce, analyzing all relevant features of social and e-commerce design, a finally proposing a new model and new principles to guide social trade [12–14].

We can say that the success of a project is based on ideal management and an adequate plan to optimize time and costs. Therefore, the best ways to program and estimate costs to implement a project must be considered. Models and methods dedicated to resource allocation, Gantt charts, network analysis models, or even mathematical models of predictions and simulations, carry enormous responsibility in the finality of the project. An eloquent study in this direction was conducted by Habibi et al. (2018) [15], where they analyzed and simulated many processes and ways of project planning. The most intensively studied are the critical path methods (CPM) but also the revision technique (PERT) is a common example of network programming, relevant articles in this direction have been published (Bhosale et al., 2017) [16]. The CPM method takes into account everything that means a project parameter, the flow of activities, and most of the clear information. We can say that Zareei (2018) [17] applied CPM to analyze the programming and planning of a bogus construction dedicated to greening. Therefore, following the application of this method in many areas, it has been found that CPM can partially reduce the uncertainty of the design, but any change or delay in any activity can lead to the unfeasibility of the final estimate. Methods have even been created to correct CPM anomalies using PERT, in which case the models and activities must be stochastic and have a certain behavior. We can say that the optimization of the PERT network has been investigated by many researchers, starting from Chanas and Kamburowki (1981), channeling their time to improve the correct estimation times in relation to the existing rules and procedures. Azaron et al. (2005) focused their efforts on developing a multi-objective model to take into account the trade-off between time and cost in PERT-type networks. As in the case of PERT, probabilistic methods tend to some problems, these methods consider that duration of activities has a constant strictly related to the probability distribution. Therefore, in this situation, the assumption of estimating the durations depends on that constant, but also on the way of estimating the parameters in the distribution. Attempts were also made by using triangular, exponential, and normal distributions, but they tended to fail. Implementation and determination of probabilistic values through such distributions, analysis of the average and variation of distributions, this being dependent on the repeatability of some activities or even on the statistical inference caused by the principle of uniqueness of projects. We can say that some inferential deduction models analyzed the duration of the activities so that later it is not taken into account [18].

Estimates of time and cost are extremely complicated due to the appearance of statistical distributions. We can say that in many cases the duration of the activities is stochastic, we cannot achieve a probability distribution function, being strictly defined during the project completion period, this being a sum of several stochastic variables. This programming being incorrect can considerably increase the project costs, but also the execution time. Therefore, the cost and duration must be evaluated according to certain parameters, and the most accurate is with the help of fuzzy sets, incorporating the opinions and experience of specialists, then outlining a nomenclature dedicated to construction. The system requirements for the design of activity planning algorithms were analyzed the current state of research in this field was analyzed. Time and cost analysis are the most important factors for planning and controlling construction projects. The selection of different sources and technologies, such as materials, labor, equipment, and methods, for carrying out an activity, is made by construction planners. In this selection process, uncertainties and risks in construction applications are taken into account depending on the region in which the project is implemented. In this respect, the duration of the project and the cost of the project must be determined according to the technique chosen in the context of regional conditions [19]. Based on the specialized data, the existing methods for developing the algorithms were analyzed and the specifications of the activity planning algorithms were defined. The latest optimization technique developed in recent years is the method of the genetic algorithm, which is based on the theory of evolution and the principles of natural selection. The genetic algorithm used for classification, model selection, and other optimization processes is the best-known method of metaheuristic optimization applied to time-cost problems

(Sonmez & Halis, 2012; Aly, 2016) [20]. Since no solution can be found for each problem using analytical or non-numerical methods, it is necessary to determine the mathematical expression of the problem. Numerical algorithms such as fuzzy logic have been developed to be used in cases where a problem cannot be expressed mathematically (Agdas, Warne, Osio-Norgaard, and Masters, 2017) [21]. In many studies, fuzzy logic and the fuzzy model are used in the time-cost trade-off.

The genetic algorithm is used to determine the minimum costs during the planned construction period of the project, and the fuzzy logic approach is used to model the uncertainties during the implementation of the work plan with the network programming technique (Akcay, 2003) [22]. The mathematical and heuristic models developed for time-cost construction compromise solutions are focused on deterministic situations. Non-deterministic methods are rarely considered on the issue of the time-cost trade-off. The estimation of costs and duration has evolved from the conceptual phases to the detailed, definitive estimates, which depend on the amount of information collected by the contractor. The application of databases in assessing the viability of a prospective project is significant in providing data on the actual cost and time of completion of a successful project. Thus, a database containing information on the estimated and actual quantities used as well as the possibility to be able to query the real-time stocks of construction material suppliers would make the estimates more accurate for both cost and duration [23,24].

This article is structured as follows: Section 1 presents the current state of the concepts developed in the field of electronic commerce, but also proposals for algorithms to optimize processes and cost estimates. Section 2 contains methodological aspects, discussion about algorithms, implementation methods, testing and validation, software architectures, but also component parts implemented in the first phase. Descriptions of the concepts presented and how they facilitate certain processes in online stores. Section 3 is highlighted by the results obtained and the impact that the Coestim solution creates in the field of construction estimates and recipes for construction materials. Section 4 also presents several discussions and ways to improve the cost estimation algorithm. Section 5 is characterized by the conclusions of this article, but also the future directions of implementation.

2. Methodology for Implementing the SaaS Solution–Coestim

Glocal Soft aims to design software as a service (SaaS) applications in the field of construction, to increase productivity in this field, apply principles of participatory economy, and develop intelligent algorithms to prevent cost overruns, risk mitigation, and business planning. With this help, both individuals and construction companies will be able to estimate the costs and duration of a construction project, find teams for the execution of each phase of the project, rent the necessary equipment, purchase the necessary materials, plan the project, monitor the progress of the project and actively participate in increasing productivity in the field of construction through the feedback given. Thus, the objective of our research will be to design a prototype application that allows us to validate the use of the principles of participatory economy in construction and validate the implementation of intelligent algorithms, aimed at increasing productivity in the construction industry. There are currently a relatively small number of specialized, organized craftsmen with well-defined working standards and prices. Most of them are without professional training. Those who have experience are not promoted for various reasons, they rely on a small circle of recommendations. The lack of transparent planning of the works, the lack of knowledge of calculations necessary to create an estimate, poor management of transport of materials-by incorrect estimation of the necessary, unavailability of urgent deliveries, and lack of interest in new products on the market, are among the weaknesses of this growing market segment. This is why the development of this unique platform is so necessary because it aims to improve the quality of the workforce, raise standards and estimate the costs of a development project. With the help of the application, the workforce in this field will be able to improve its customer portfolio, get positive reviews and feedback, receive information from suppliers, and use the currency program. Any construction company can make available the resources it has, human and material, and their relative occupancy over time, actively participating in a collaborative economy. By creating standards in this area, and later applying machine learning algorithms, we will be able to create correct planning of projects in construction, taking advantage of the availability of local resources and their possibility to be "borrowed". It is a unique application in the field of construction and landscaping, whose main objectives are to increase productivity in the construction industry, improve the quality of labor, raise standards and estimate the costs of a landscaping project [25].

2.1. Key Concepts in the Development of Dedicated Software Solutions

Construction engineering and management (CEM) is going through constant innovations toward digitalization and intelligence, to achieve a considerable leap in automation, productivity, and reliability. That is, the construction industry is being reshaped along the entire value chain of construction, including planning, construction, operation, and maintenance (O&M). EMC can be divided into two parts: one is construction, engineering and the other is construction management. Construction engineering can be defined as a completed process, including design, programming, budgeting, and construction itself. Proper management over the life of a project is a necessity for all kinds of construction projects, aiming to guide the project to success under the control of time, costs, field, quality, and collaboration [26]. Project managers coordinate closely with other participants to draw up plans, schemes, deadlines, costs, staffing arrangements, and others for construction management. They monitor the entire progress of the work, focus on all aspects of the project (e.g., labor, capital, time, equipment, material, risk), and then give back the appropriate instructions to reduce the possibility of delays, budget overruns, high risks, and major conflicts. In order to launch real digital strategies in EMC, artificial intelligence (AI) acts as the backbone to change the way a construction project is carried out.

2.2. Benefits of Artificial Intelligence in CEM

Automation: AI leads the project management process automatically, technically, and objectively.

Risk mitigation: AI can monitor, recognize, evaluate and predict the potential risk in terms of safety, quality, efficiency, and cost between teams and work areas even under high uncertainty. AI-based risk analysis can provide assistance and predictability on critical issues, helping project managers quickly prioritize potential risks and lead to proactive actions such as streamlining site operations, adjusting staffing, and maintaining projects on time and on budget. In other words, AI presents valuable opportunities to perform early troubleshooting to prevent unwanted failures and accidents in the complex workflow.

High efficiency: another important use of AI techniques is in optimizing the project by solving problems, aiming to achieve the construction project as efficiently as possible. For the construction industry, prediction is an important strategic task for project control rather than empirical methods. AI is expected to classify, quantify and anticipate potential risks related to project performance and their relevant impacts, in order to conduct a reliable diagnosis and analysis of broad aspects of project performance, such as planning, buildability, safety, productivity, and more.

The predicted results can therefore serve as basic knowledge to guide proactive management, aiming to ensure the effectiveness and reliability of the project against its objectives. For example, unwanted delays can inevitably lead to lower efficiency, cost overruns, and other negative effects, so predicting possible construction delays can help uncover key blockage factors and track a high-precision estimate over the life of the project. AI helps to accurately perceive the safety risk of structural systems in advance, therefore, immediate action can be taken to reduce the possible risk. By maximizing expected effects, optimization can make a process adhere perfectly to a set of criteria and constraints. Usually, popular meta-heuristic optimization algorithms have been widely applied for the planning, construction, and maintenance of construction projects. They can consistently provide recommendations not only to minimize the duration and costs, but also to maximize productivity and safety. For example, based on the optimized objectives of the project, the appropriate plans in terms of strategy, operation and program can be formulated at the planning stage, as an important premise for the success of the project. At the execution stage of construction tasks in a complicated location, optimization helps to better allocate resources, arrange staff, establish facility arrangements and make appropriate adjustments in a reasonable and timely manner. The Application Programming Interface (API) is a standard set of agreed-upon protocols, rules, routines, and tools for creating and building software applications. The API defines the modes and rules of interaction between different software applications and/or components of the same application. The API is a versatile technology because the design is not limited to a particular language or programming technology. APIs include specifications for data, routine structures, classes, and attributes of objects/variables; this is the backbone for using the provided API.

Construction and decision-making problems are most effectively modeled using fuzzy logic and fuzzy hybrid techniques when:

- Problems are characterized by subjective uncertainty and ambiguity.
- There is a reliance on experts to make quick decisions, using subjective information and approximate reasoning based on their experience rather than accurate numerical data.
- Problems are characterized by inaccurate inputs and outputs and imprecise or unstructured variables, which require heuristic reasoning based on experience and judgment rather than algorithms.

Fuzzy machine learning techniques are often used in construction for modeling or predictive classification. With the advent of new technologies for automatic data collection, storage, and analysis, construction industry organizations have increased the amount and types of data they collect, this change leading to a greater interest in machine learning.

Due to the importance of the role of cost estimation in a project, different predictive methods have been proposed. Approaches to cost estimation range from statistical-based multivariable regression analysis to machine learning techniques such as Classification and Regression Trees (CART), M5 Tree Model (M5-MT), Artificial Neural Network (ANN), and vector support machines (SVM).

- CART is a classification method that uses historical data to build decision trees. A CART model that predicts the value of continuous variables in a set of input variables is known as a regression model. A major advantage of the decision tree-based model is its ability to manage a small data set. However, a disadvantage is that it can produce unstable decision trees. The reason is that the insignificant change in the learning sample could lead to radical changes in the decision tree.
- The tree model (MT-tree model) is proven to have the ability to learn effectively and can address high-dimensional regression tasks. Compared to other machine learning techniques, the MT training process is relatively fast and the results are interpretable.
- ANN is a viable alternative for forecasting, construction costs and, in practice, has been used to build various cost prediction models. This method eliminates the need to find a mapping relationship that mathematically describes the construction cost based on the input variables. When the influencing factors and the structure of the ANN are specified, the task is to collect a reasonable amount of data for ANN training. However, the process of training ANN-based models is often time-consuming.
- In the construction area, SVM was used in cost estimation. The principles are based on structural risk minimization and statistical learning theory. SVM-based models also involve the identification of influencing factors, data sample collection, and the training/testing process. After establishing the mapping function, the model is able to predict the future value of the project cost. The advantages are widely known for accurate prediction ability. However, the SVM training process involves high computational costs.

2.3. Software Applications Dedicated to Construction Project Management

2.3.1. Archdesk

Due to the planned design of a centralized repository of sensory data on construction workers and a wide range of data operating in the Archdesk system, as well as data from external sources (e.g., metadata), it will be possible to be warned of the various delays in construction projects. By analyzing this data to detect patterns, using artificial intelligence algorithms, they will finally be able to provide data to the end-user in the form of an early warning system for adverse events, mitigating their risk and supporting key decision-making. This will directly translate into optimizing the economic aspects of construction projects and their timeliness (anticipating and counteracting delays). Predictive processes will use innovative methods to detect dependencies and patterns in high-volume data sets. Archdesk, thanks to the new technology developed because of the project, will be able to automatically detect the risk of delay or increase in project costs and will allow the employee to specify the nature of a certain delay or problem, which will positively increase the accuracy.

2.3.2. SocrateERP

SocrateERP provides an integrated application to companies operating in the field of construction and helps to efficiently manage all processes in the company: procurement, contract management, costs, consumption, employees, equipment, and machinery, maximizing profit through the efficient execution of each project and the possibility managing more projects with fewer resources, by integrating and automating key processes. The application involves:

- Management of construction works-efficient development of all construction works, quantitative-value records of all activities, by projects, phases, and sub-phases;
- Cost control per project;
- Management of equipment and machinery-planning and tracking, on-site, of equipment and machinery, consumption being recorded in the machine sheet;
- Time management-both the human resources involved in the construction works and the Tesa staff;
- On-time supply-Quality control and stock level;
- Sales management-Management of the sales process;
- Financial accounting management;
- Integration with budgeting and project management software;
- Industry-specific analyzes and reports.

2.3.3. Solvidev

The Solvidev program contains everything you need to participate in public tenders: old rules-new rules-even your own rules made by material suppliers-new technologies-all the forms needed-execution schedule-online video help-project management-settlements-plus assimilations between the materials in the rules and those from suppliers. Includes:

- Database-over 50,000 estimate rules (from 1981 to 2017);
- Over 100,000 materials with updated prices from over 71 suppliers;
- All forms and reports required to participate in public tenders;
- General estimate;
- Execution schedule complete with recommended days required for each item;
- Optimized project management in the field of construction and installations;
- Unlimited addition of beneficiaries, investments, objects, currencies, new materials, labor, and equipment, attached list of new materials, and equipment.

2.4. Regression Model and Fuzzy Logic Techniques

To estimate the costs, it is necessary to use a regression model, which has an equation for each case according to a statistical standard that contains the best subset. Therefore, this test can determine the best probability of properties and characteristics to display some relationships between the estimated value of the costs and the variables considered. We can say that the relationships between cost estimation and assumed variables come from previous sets. Thus, the correlation between the variables is not allowed in a regression-type model, an aspect that can be evaluated by using the absolute relative error correction (*ARE*), which is defined as follows, in Equation (1):

$$ARE = \frac{|Acualcost - Estimatedcost|}{Actualcost} \tag{1}$$

To use the best test for the available data subsets, we can analyze the case study [24]. The regression model can express the relationships between cost and variables, as follows, in Equation (2):

$$z_i = z_0 + \sum_{k=1}^{p} z_k x_{ik} + \sum_{kk}^{p} z_{kk} x_{ik}^2 + \sum\sum z_{kk} x_{ik} x_{ij} \tag{2}$$

where, p represents the number of predicted variables, n is the number of simple data i = 1, $\ldots\ \ldots$, n and $z_0, z_1, \ldots\ldots, z_p$ are the parameters, $x_{il} \ldots, x_{ip} \ldots$ are constantly known. We can say that these parameters z_0, z_k, z_{kk}, z_{kj} are determined by the regression of the smallest extraction squares that minimizes the sum of the deviation squares $\hat{}z(x)$, values that are predicted as nominal from the real initial value $z(x)$ [27–29].

2.5. Fuzzy Logic Techniques

To give a more accurate example, a schematic diagram has been outlined showing the use of fuzzy logic, which is composed of four main stages, namely, fuzzification, fuzzy rule base, fuzzy inference engine, and also defuzzification presented in the logic diagram in Figure 3. We can say that in the fuzzification stage, numerical maps are introduced in the form of fuzzy data sets associated with a recursive value.

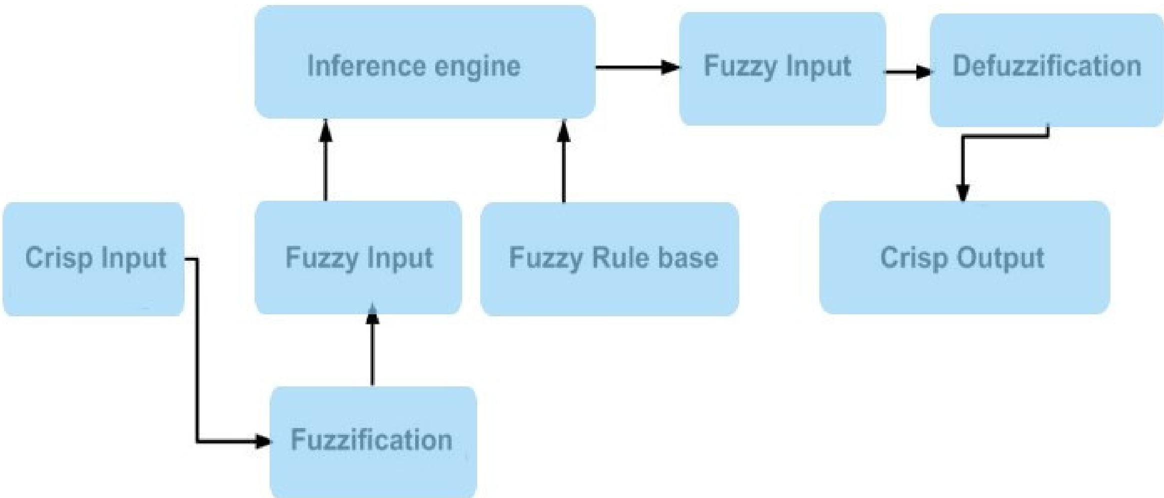

Figure 3. Illustration of the general diagram of a fuzzy system.

When a fuzzy set, O, is defined on the set X, the domain of the fuzzy variable is characterized by its belonging to $\mu_U(x)$, being in the range [0,1], expressed as follows in Equation (3):

$$O = \{(x, \mu_U(x)) \backslash x \in X,\ \mu_U(x) \in [0,1]\} \tag{3}$$

Therefore the membership function is defined for any unclear set, applying it also to the input parameters in order to determine the degree of truth. According to fuzzy principles, see Figure 3, the way to acquire basic information is at the beginning of every algorithm for building an expert system. We can say that the properties imposed in the form of IF-THEN rules can be assimilated from the analyzed data. The accumulation of well-defined rules and properties builds a fuzzy system that is based on these characteristics. Any rule starts from a premise invoked by "If" and "Then", the existence of logical operators such as "And, Or, No", is used for the connection depending on the rules applied to the parties. We can say that the last step in such a process is Defuzzification, it has the role of converting the unclear data sets that are output to a clear value [29]. This step can be performed by several methods, and the most used is exemplified by the Equation (4):

$$Centroid = \frac{\int_x \mu_U(x)xdx}{\int_x \mu_U(x)dx} \tag{4}$$

3. Prototyping and Proposed Implementation

3.1. Designing Project Creation Simulator—Coestim

Optimizing an application's architecture starts by simulating the performance characteristics of that architecture using a software tool called a simulator. Simulators are essential elements in research because they have their main advantage the great flexibility in designing new architectures as well as in improving the existing architectures. After all, the time required for the development of a software simulator is much shorter. In addition, development costs are lower, and it is easier to resolve errors and problems. In the Coestim project, a series of models were made with the help of which we can build a hierarchical structure of a construction project. Each level of the hierarchy is defined as a service that has a list of materials used, a list of necessary resources, and a list of other services on which it depends to be executed, see Figure 4.

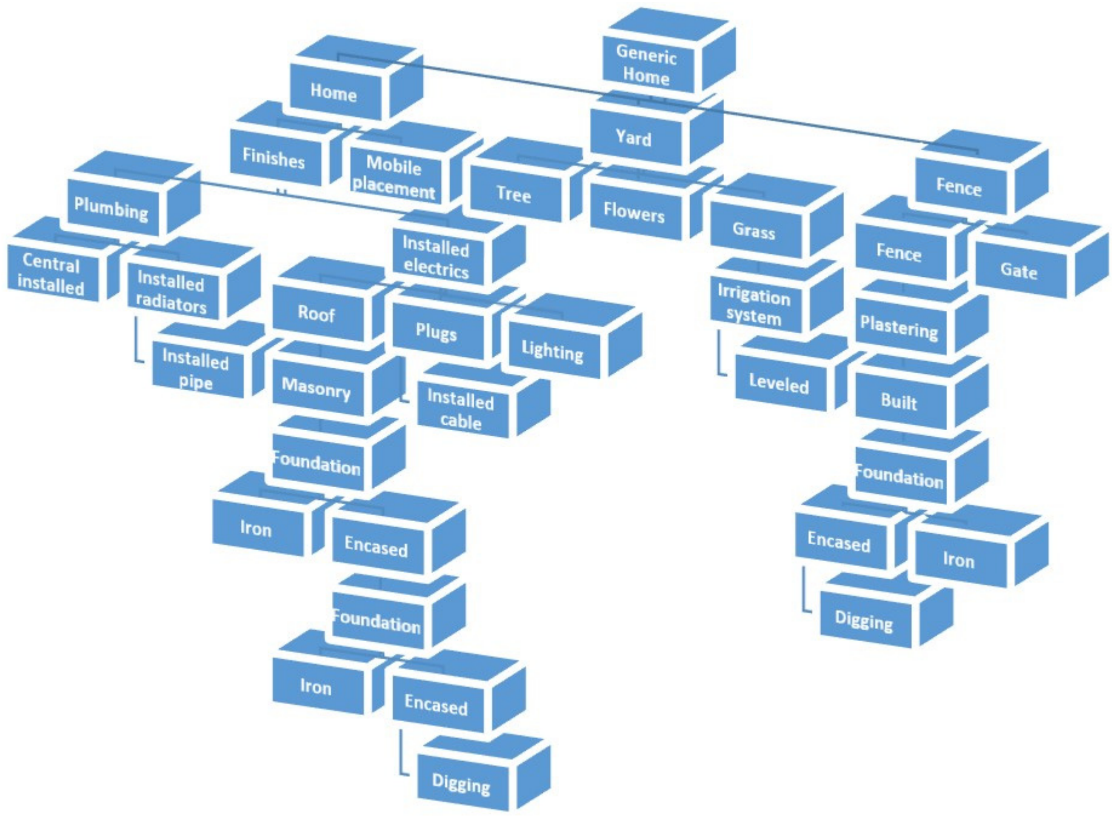

Figure 4. Conceptual diagram of the database dedicated to the Coestim planner.

Simulation algorithms for project creation have also been implemented. The project creation simulation algorithm is implemented in the following steps:

1. Going through all the hierarchical structures of the super-services:
    - All parent super services are identified;

- For each super-parent service, the list of children is taken over;
- For each parent-child structure a random number is created between one and five projects with an initial number of estimates which is incremented at each iteration and values of service quantities, where the initial values are multiplied by the iteration number.

2. Adding estimates to the project:
   - Each super-service sequence is recursively traversed to create estimates in the same parent-child structure;
   - The project-estimation link is created;
   - For each estimate, the details specifying the items used in making it together with the prices and quantities thereof shall be added;
   - For each estimate, add the resources used in its estimate.

It was proposed to create, with the help of an artificial neural network, a design for the conceptual estimation of the length of a residential construction project. This proposed integrated model predicts the project completion time. Preliminary estimates of project parameters were based on the material estimate, which is the most vital information present for the potential project, as defined in the completed project database. The proposed artificial neural network system will be created in three phases. The three phases are vital in forming a precise ANN for predicting the time of a project. In addition, the quality and applicability of the data in the training database were considered the most fundamental elements to determine the accuracy of the forecast:

1. **Modeling phase:** In this section, the ANN was modeled by defining the network architecture in which a series of parameters such as the number of layers, input parameters, and the number of neurons are defined. In addition, the amount of output data, the activation functions of the neuron, and the type of training function based on the network orientation were described.
2. **Training phase:** ANN training was based either on the training of this network structure or the weight of the training. In this section, the training algorithm was selected as supervised, unattended, or reinforcement training.
3. **Testing phase:** involves comparing the results of the proposed ANN model. This exercise is based on the data set for testing with the prospected values.

The proposed methods for designing intelligent algorithms for activity planning were analyzed.

3.1.1. Schedule with Earliest Start Date

This function is recursive and calculates the start and end dates of each activity, depending on the total duration in hours and starting from the start date. Figure 5 presents an example:

```
private void ScheduleWithtEarliestStartDate(Estimate estimate, DateTime startDate)
{
    estimate.EaliestStartDate = AddBusinessDays(startDate, GetDaysFromDurationInHours(estimate.TotalEstimateDuration));
    estimate.EaliestEndDate = AddBusinessDays(estimate.LatestStartDate, GetDaysFromDurationInHours(Duration(estimate)));
    estimate.LatestStartDate = SubstractBusinessDays(estimate.LatestEndDate, GetDaysFromDurationInHours(Duration(estimatE)));
    foreach (Estimate childEstimate in estimate.EstimateChildren)
    {
        childrenEstimate.LatestEndDate = estimate.EarliestStartDate;
        ScheduleWithtEarliestStartDate(childEstimate, startDate);
    }
    }
```

Figure 5. Pseudocode, which calculates the start and end, dates of each activity, depending on the total duration in hours and starting from the start date.

3.1.2. Get Days from Duration in Hours

This function returns the number of working days using the duration in hours, see Figure 6.

```
private int GetDaysFromDurationInHours(double GetDaysFromDurationInHours) {
    return (int)Math.Celling(GetDaysFromDurationInHours / 8);
}
```

Figure 6. Pseudocode for calculating the duration in hours.

3.1.3. Calculate Total Estimate Duration

This function calculates the estimated total hours for the duration of a service, being shown in Figure 7.

```
private void CalculateTotalEstimateDuration(Estimate estimate)
{
    double sum = 0;
    foreach (Estimate childEstimate in estimate.EstimateChildren)
    {
        CalculateTotalEstimateDuration(childEstimate);
        sum += childEstimate.TotalEstimateDuration;
    }
    estimate.TotalEstimateDuration = sum;
    }
```

Figure 7. Pseudocode for calculating time estimation.

3.1.4. Add Business Days

This function calculates the date by adding the number of working days, see Figure 8.

```
public static DateTime AddBusinessDays(DateTime date, int days)
{
    if (days < 0)
    {
        throw new ArgumentException("days cannot be negative", "days");
    }
    if (days == 0) return date;
    if (date.DayOfWeek == DayOfWeek.Saturday)
    {
        date = date.AddDays(2);
        days -= 1;
    }
    else if (date.DayOfWeek == DayOfWeek.Sunday)
    {
        date = date.AddBusinessDays(1);
        days -= 1;
    }
    date = date.AddDays(days / 5 * 7);
    int extrDays = days % 5;
    if ((int)date.DayOfWeek + extraDays > 5)
    {
        extraDays += 2;
    }
    return date.AddDays(extraDays);
}
```

Figure 8. Pseudocode for calculating the number of working days.

The algorithms for calculating the probable data for the execution of the projects are applied, see Figure 9.

```
public async Task<IActionResult> Simulate()
{
    var parentSuperServices = await +parentSuperServices.GetAllWhereAsync(new parentSuperServiceQueryResource { OnlyParentsSuperServices = true});
    if (parentSuperServices.Any())
    {
        foreach (var superService in parentSuperServices)
        {
            var superService = new List<SuperService>();
            try
            {
                {
                    superServices = await GetSuperServiceChildren(superService.Id, superServices);
                    superServices.Add(superService);
                    Random random = new();
                    var noOfIterations = random.Next(1,5);
                    for (int i=1; i <= noOfIterations; i++)
                    {
                        var project = await _projectService.CrateAsync(new Project { Name = $"Proiect {superService.Name}_{i}"});
                        if (i > 1)
                        {
                            superServices.ForEach(x =>
                            {
                                x.NoOfEstimates++;
                                x.ServiceQuantity *=i;
                            });
                            }
                            await PrepareEstimates(_mapper.Map<SuperServiceDto>(superService), _mapper.Map<List<SuperServiceDto<<(superServices), project.Id);
                        }
                    }
                    catch (Exception)
                {
                }
            }
            for (int i = 0; i < estimateList.Count; i++)
            {
                var childrenEstimateInclude = await _estimateService.GetEstimate(estimateList[i]);
                await CalculateTotalEstimateDuration(childrenEstimateInclude);
                await EstimateRealisticDatesWithEarliesStartDateAsync(createEstimateInclude, DateTime.Now);
            }
            }
```

Figure 9. Pseudocode example dedicated to the implementation of services.

3.2. Project Execution Simulator Design–Coestim

At this stage of the project, the system requirements for the design of the project execution simulator were defined. For each activity scheduled to be performed, the execution simulator added disturbances in the execution of projects in the range of −30% + 30%.

The project execution simulator has the following assumptions:

- The simulator will not change the providers of a service or their resources
- An activity cannot be divided between resources from different providers
- Resources are limited in quantity and number of hours per day
- The number of resources allocated to an activity in a given project will remain constant until the end of the activity.
- However, the number of resources allocated to an activity may vary from project to project.
- It is assumed that resources maintain a constant level of productivity throughout the activities.
- An activity has a maximum number of resources that can be allocated at the same time.

Based on the information, it was established that the project execution simulation algorithm should be implemented in the following steps:

- Each project is taken over
    - o The list of estimates for each project is taken over;
    - o An execution is created for each estimate;
- Allocate resources for each running estimate
    - o The required resources are taken over;

- For the necessary resources, we are looking for suppliers who can provide the necessary resources;
- If we do not find a supplier for one of the resources, there will be an exception stating its lack;

- Employee allocation for each resource
  - For each resource the number of assigned employees is sought;
  - If there are no employees for one of the resources, an exception will be given stating their lack;
- Start activities
  - Go through the hierarchy of executed estimates and simulate the start and end dates of the activities according to the number of hours required for each resource;
  - Update start and end dates for each execution stage.

3.3. Designing Intelligent Algorithms for Cost Efficiency–Coestim

In this stage of the project, the system requirements for the design of cost efficiency algorithms were defined and the proposed methods were analyzed to identify the best solution. As most of the processes of construction companies are digitized, a critical element will be the evolution of the traditional supply chain to an interconnected, intelligent, and efficient market.

Today's supply chain is difficult, going through a series of steps from marketing, product development, production, and distribution and finally into the hands of the customer. Digitization will automate those steps, and the chain becomes a fully integrated ecosystem that is fully transparent to all actors involved-from construction companies to suppliers of materials, components, and parts, to the carriers of those goods, and, ultimately, to customers. We set out to develop an algorithm in which material suppliers, distribution companies, and construction companies offer and contract construction projects but also parts of projects, activities, or stocks of materials, through tenders in a regional works exchange. In this research, a genetic algorithm develops bidding strategies to optimize the profitability of projects and identify collaboration opportunities, with the ultimate goal of cost efficiency. For the calculation of the best price, the other offers for the items used to create the service will be taken into account.

Steps needed to identify a better offer:

- Other possible offers are being sought;
- If other offers are found, check if there is a better price between them than the one initially set;
- If a better price is found, the costs are calculated with the new price.

In order to implement this module, an example of pseudocode shown in Figure 10 was built.

3.4. Designing Intelligent Algorithms to Optimize the Development of a Project–Coestim

In this stage of the project, the system requirements for the design of project development optimization algorithms were defined and the proposed methods were analyzed to identify the best solution. The objective of Coestim was to improve the algorithms developed in the research so far by adding the possibility to search for resources, both material and human, in real-time, directly in the systems from different providers and service providers, taking into account an initial risk which that each present. As well as the feedback history from all customers who have used the supplier's products or services, thus developing the principles of participatory economy in construction. After more than ten years of study, both the effectiveness of the application and its theoretical basis have shown that the problems of limited allocation of resources can be solved by the technique ACO (Optimization of ant colonies) where the goal is to minimize total time and project risk, with resource availability and precedence relationships as constraints.

After calculating the conceptual time of a project using activity-planning algorithms, it was proposed to optimize the use of resources by developing intelligent algorithms to optimize the development of a project.

```
0 references
private async Task FindPossibleSmallerPrice(List<Estimate> estimates)
{
    foreach (var estimate in estimates)
    {
        var projectExecutionItems = await _projectExecutionService.ProjectExecutionItemsByEstimateId(estimate.Id);
        if (projectExecutionItems.Any())
        {
            foreach (var projectExecutionItem in projectExecutionItems)
            {
                var itemOffers = await _supplierItemRepository,GetWhereIncludeAsync(x => x.ItemId == projectExecutionItem.SupplierItem.ItemId, x => x.Include(sip => sip,Prices));
                var prices = PreparePrices(ItemOffers, projectExecutionItem.Quantity);
                var minPriceItem = prices.OrderBy(x => x.Value.Item1).FirestOrDefalut();
                if (minPriceItem.Key != [projectExecutionItem.SupplierItemId && minPriceItem.Value.Item1 < projectExecutionItem.SalePricePerItem)
        {
                projectExecutionItem.SupplierItemId = minPriceItem.Key;
                projectExecutionItem.SalePricePerItem = minPriceItem.Value.Item1;
                projectExecutionItem.RecomendedPricePerItem = minPriceItem.Value.Item2;
        }
            }
        }
    }
}
1 reference
private Dictionary<int, Tuple<decimal?, decimal?>> PreparePrices(List<SupplierItem> supplierItems, double itemQty)
{
    Dictionary<int, Tuple<decimal>, decimal?>> prices = new Dictionary<int, Tuple<decimal?, decimal?>>();
    foreach (var supplierItem in supplierItems)
    {
        var supplierItemPrices = supplierItem.Prices;
        if (supplierItemPrices.Count >0)
        {
            var orderByQuantityPrices = supplierItemPrices.OrderBy(x => x.Quantity).ToList();
            var index = intemQty >= orderByQuantityPrices.Max(x => x.Quantity) >
                orderByQuantityPrices.Count - 1:
                orderByQuantityPrices.IndexOf(orderByQuantityPrices.LastOrDefalut(f => itemQty >= f.Quantity) >> orderByQuantityPrices[0];
                if (index != -1)
                {
                    prices[supplierItem.Id] = new Tuple<decimal?, decimal?>(supplierItemPrice[index].SalePrice, supplierItemPrice[index].RecomendedPrice);
                    }
                }
    }
    return prices;
}
```

Figure 10. Pseudocode for designing intelligent algorithms for cost efficiency.

The developed algorithm is based on the following hypotheses:

- A resource cannot be divided into several activities on the same day;
- An activity cannot be divided on resources from different providers;
- For a certain activity, if any provider of a child activity has the necessary resources to carry out the activity, the algorithm will take into account only those resources and will not look for other providers;
- Resources are limited in quantity and number of hours per day;
- The number of resources allocated to an activity in a given project will remain constant until the end of the activity;
- However, the number of resources allocated to an activity may vary from project to project;
- It is assumed that resources maintain a constant level of productivity throughout the activities;
- An activity has a maximum number of resources that can be allocated at the same time.

Testing the application is extremely important. For example, if the software GUI displays a success message after adding a new entity, it is considered that this data has been completely stored in the database. However, a malfunction may occur during this operation without being displayed in the software interface. In this scenario, differences in status/content in a database between different operations can help identify potential software failures. However, manual checking for these differences is a daunting and time-consuming task. Thus, automated testing would be an interesting solution to quickly and efficiently perform functional testing in database-based applications.

In this case, the issue of testing the Coestim database was addressed to verify the integrity and consistency of the data. The importance of testing the database was presented and the types of tests that can be performed both by queries and by tools dedicated to this procedure were described. Database tests have been performed involving:

- Schedule validation
- Check tables and columns
- Checking keys and indexes
- Verification of stored procedures
- Avoid duplicates.

"Functional database testing" is a type of database testing that is used to validate the functional requirements of a database from the end user's perspective. The main purpose is to test whether the transactions and operations performed by the end-users related to the database work as expected or not. "Non-functional testing" in the context of database testing can be classified into different categories, according to the requirements of the application. Things like response time under stressful conditions are considered in this step, see Table 1.

Table 1. Testing the database and analyzing its performance in relation to the number of connections.

Transaction per Client	Processed Transactions	Tps (Includes Database Connection Time)	Tps (Excludes Database Connection Time)
10	100	293.59	346.15
20	200	724.76	860.19
30	300	1012.95	1186.24
50	500	1567.23	1807.44
80	800	1815.44	2062.78
100	1000	2082.27	2344.75
500	5000	4056.35	4202.20
1000	10,000	4600.27	4714.37
5000	50,000	5614.74	5649.15
10,000	100,000	5984.69	6003.97

Tps (transaction per second).

Database performance testing was also performed using Pgbench which is a simple performance testing program for PostgreSQL databases. Runs the same sequence of SQL commands repeatedly, possibly across multiple concurrent database sessions, and then calculates the average transaction rate (transactions per second). A test scenario was prepared: 10 clients (concurrent sessions) distributed over 2 threads were considered and tests with a different number of transactions were performed for each client.

Example for database connection:

pgbench −U Postgres −p 5433 −c 10 −j 2 −t 10 Coestim
-U database user; p-port server; c-number of customers; j-number of threads; t- number of transactions per customer.

Graphical representation of the simulation order processing process (TPS) is shown in Figure 11.

An Apache test tool was also used to analyze and measure the performance of applications, various software services, and products.

Optimizations have been made regarding the performance of the database, bringing a series of changes:

- Given that the population of the database with articles is conducted by taking them from the systems of suppliers, to identify the article easier for the supplier added a text column to the entity "SupplierItem" containing a link to the article from the supplier. In the entity, "SupplierFeedOutModule" the column "CustomItemBaseMapping" is deleted because during the implementation the column "ItemBaseMapping" proved to be sufficient to save the mapping of an article to a chosen file format. A column has been added containing a code for both services and resources to make them easier to identify.

- Price and quantity columns were renamed and the data type was changed to "EstimateItem" and "ProjectExecutionItem", according to their name and type in "SupplierItemPrice". The "SuperServiceResource" entity has been filled in with the necessary columns to specify the number of hours required for a resource and to indicate whether it is on the entire super-service. There were also changes in the data type for the quantity column in the entities "ServiceResource" and "EstimateServiceResource" to accept real values.

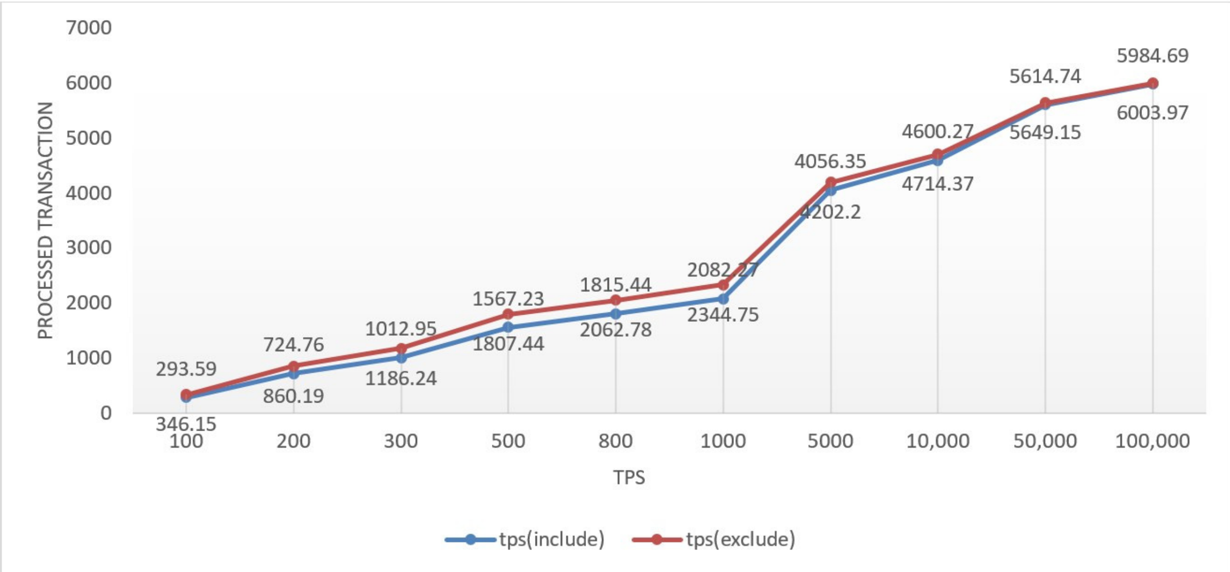

Figure 11. Graphical representation of the simulation order processing process (TPS).

4. Discussion

Planning tools are usually used to predict when an order will be ready, in other words: planning ultimately refers to predicting delivery times in a production system, but what determines the delivery time? The most important factor that influences the payment time is the occupancy rate. The occupancy rate is the percentage of time that work is available at a workstation. Therefore, an occupancy rate of 80% means that work is available 80% of the time and that there are no orders for 20% of the time. The strong influence of a high occupancy rate on delivery time implies that even small errors in estimating order time can have a major impact on delivery time. Because time estimates can easily have a margin of error of 5−10%, it is, therefore, no surprise that an accurate prediction of delivery time is difficult. A second effect that complicates planning is the effect of variability. Two types of variability influence planning. On the one hand, there is process variability. Therefore, we consider the developing solution, Coestim, to be extremely important and useful, which outlines a dynamic and extremely versatile application in the field of issuing construction estimates based on the need of the user's requirements. The algorithm developed and being implemented and tested wants to optimize 100% all the necessary processes, being unique in the way it works. Figure 12 shows the first UI version of the Coestim application dedicated to the field of construction and currency generation. Being in the stage of implementation and continuous improvement, the application is in the process of pre-testing and optimization. Coestim is based on the latest implementation practices and the most important factors for improving communication and data processing performance, regardless of the size of the bundle files. Any module added from third projects, creates new dependencies, being different from the main ones. During the implementations, it was observed that in the case of the entities on which CRUD operations were performed, a larger number of components were generated. These were loaded into an extremely simplistic listing layout. Therefore, for each entity, those components must be generated within the same instance of the listing layout.

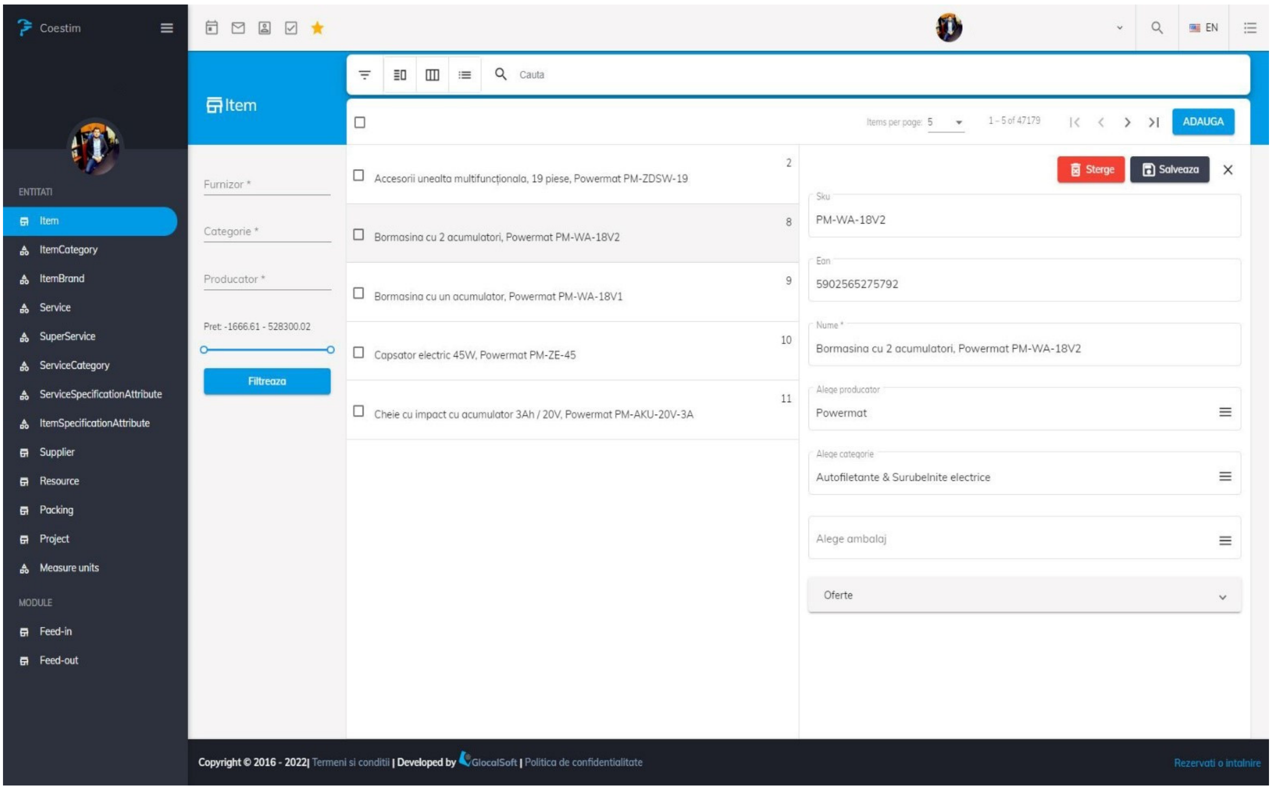

Figure 12. UI interface of the Coestim application.

Thus, Coestim benefits from a layout capable of implementing a new generic logic that manages all CRUD operations. In other words, the new layout contains several components, but only the entities that will implement the layout define a single initialization component. This layout creates a generic module that can be loaded into the loop as many times as needed within the application through a dynamic-dialog module, making it easy to list and process data from any area of the application.

5. Conclusions

We can say that the Coestim application at this stage can be adopted in almost all European Union countries, being modular and allowing integration with any type of billing program, databases, e-commerce platforms, and marketplaces. The field of construction can be revitalized, but at the same time, propelled by feasible solutions that substantially improve the area of design and generation of estimates dedicated to construction. Some approaches target Coestim for future implementations, and dynamic Lean or QRM principles to constantly improve the designed algorithms. Time is a vital resource both in people's lives and in computer processes, any delay can cause the unfeasibility of a project. Coestim includes both e-commerce, professional construction services, and working estimates, but also direct contact with suppliers of construction materials. An end user only needs to enter the necessary data and the Coestim application will generate a working estimate to which several versions are attached which include work teams, services, quantity prescriptions, and price offers from companies. All these features of the application led to a database populated with over 150,000 items shortly after the launch of the first version of the application.

The constant implementation and development of new modules and algorithms facilitate and drives the application in terms of customer demand. We believe that this approach can revitalize and can be a challenge for the entire field of construction both in Romania and in Europe. Future implementations will aim to incorporate all types of ERP and synchronize with any type of existing platform internationally to outsource the application to other existing markets. Coestim wants to introduce new standards in the way we work in the field of construction and increase the quality of related services. We can say that we want to increase the commitment to customers and at the same time drive e-commerce in the field of construction.

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