I/O Operations. Fetching data from storage devices, whether for loading new areas or assets, can introduce latency and disrupt gameplay flow.

Network Synchronization. In multiplayer or online games, network latency and synchronization can lead to lag and connectivity issues, affecting the overall gameplay experience.

The problem of a chain reaction of a distributed performance bottleneck on a software performance bottleneck.

One notable challenge arises from the intricate interplay between distributed and software performance bottlenecks. As games increasingly adopt distributed technologies to accommodate multiplayer, cloud-based streaming, or seamless scenes, the potential bottlenecks are no longer isolated between themselves. Instead, they form a chain of dependencies, where a bottleneck in one area can trigger a cascade of issues affecting other components.

For instance, a slow response from a network service due to distributed bottlenecks can lead to software bottlenecks as the game waits for data, causing visible stuttering or delays. Conversely, a software bottleneck, such as inefficient rendering, can exacerbate distributed issues by overloading network connections with excessive data requests.

Therefore, there is a need for a comprehensive study, which is as follows.

Given the complex interactions between distributed and software performance bottlenecks, there is a clear need for comprehensive research and analysis. This entails the following.

Integrated Approach. Researchers and developers must adopt an integrated approach considering distributed and software bottlenecks. Solving one type of bottleneck without addressing its impact on the other can result in suboptimal solutions.

Realistic Testing Environments. Creating testing environments that accurately simulate real-world scenarios, including various hardware configurations and network conditions, is crucial for identifying potential bottlenecks and their interactions.

Advanced Profiling Techniques. Profiling tools and performance monitoring software should be refined to provide insights into the combined effects of distributed and software bottlenecks.

Continuous Adaptation. As technology evolves, so do the challenges posed by performance bottlenecks. Research in this field should be ongoing, adapting to new hardware architectures, networking technologies, and gaming paradigms.

In conclusion, studying performance bottlenecks becomes complex as computer games become more intricate and reliant on distributed technologies. The dynamic interplay between distributed and software bottlenecks necessitates a holistic approach to research and optimization. By studying both types of bottlenecks in tandem, developers can create games that offer seamless, immersive experiences, even in the face of increasing technical demands and expectations from players.

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RESEARCH ON THE ESTIMATION OF PROCESS MODELING EFFORT AND COST

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Abstract. *In this study, the relevant problem of the design and development of the software solution for estimation of business process modeling effort and cost has been solved. The creation of a software solution for estimating business process modeling effort and cost is a significant accomplishment since it enhances efficiency, accuracy, and resource optimization. The object of this study is the process of estimation of business process modeling effort and cost. The Subject of the study is the software solution for estimation of business process modeling effort and cost. The study aims to improve the process of estimation of business process modeling effort and cost.*

Problem statement. Estimating the effort and cost of business process modeling is critical for organizations seeking to increase operational efficiency, manage resources efficiently, and drive

successful process transformation programs. Accurately estimating process modeling effort and cost is critical for proper resource planning, budgeting, and decision making throughout the project lifecycle.

Organizations can use effort estimation to calculate the amount of time and human resources required for process modeling tasks. It helps to allocate appropriate skill sets, ensuring that the necessary expertise is available for each activity. It also allows organizations to anticipate potential bottlenecks or resource constraints and adjust project schedules or resource allocation accordingly.

Cost Estimating helps organizations understand the financial impact of process modeling activities. Organizations can create realistic budgets and successfully manage project finances by accurately forecasting expenses. This enables improved cost control, prevents budget overruns, and aligns process modeling projects with allocated resources.

Organizations can benefit significantly from the development of specialized software tools for estimating business process modeling effort and cost. These tools can provide an organized and methodical approach to predicting effort and cost, taking into account elements such as process complexity, task interdependencies, resource availability, and historical data. These specialized tools, which use process modeling algorithms and models, can provide more accurate and reliable estimates than general project management systems.

Study aim and tasks. The object of this study is the process of estimation of business process modeling effort and cost. The Subject of the study is the software solution for estimation of business process modeling effort and cost. The study aims to improve the process of estimation of business process modeling effort and cost.

The following tasks must be completed in order to fulfill the research purpose:

1) propose an approach for estimation of business process modeling effort and cost;
2) develop the software implementation of the proposed approach;
3) use the software to estimate business process modeling effort and cost.

Research results. The COCOMO (Constructive Cost Model) [1] is a popular software cost estimating model created by Barry Boehm in the late 1970s and modified in successive iterations:

$$PE = m \cdot KLOC^n,$$

where m is the factor; n is the metric number; $KLOC$ is the kilo Lines of Code (LOC).

Projects are classified in three complexity classes [1]:

1) “organic mode” for easy projects ($m = 2.4, n = 1.05$);
2) “semi-detached” for medium difficult projects ($m = 3, n = 1.12$);
3) “embedded” for complex projects ($m = 3.6, n = 1.2$).

It is not possible to predict LOC in advance in process modeling. One way for estimating LOC is to enumerate tasks using a method to be described and infer LOC from this based on the modeling language used [1]. Business process modeling supports both graphical and textual models, both of which result in source code. This source code is connected to XML in the case of BPMN 2.0 (Business Process Model and Notation) [1]. Every modelled element (task, interaction, message flow, etc.) is represented in this source code by a specific (minimum) number of lines of code.

– Activity – 6 LOC;
– Artefact – 6 LOC;
– Message – 10 LOC;
– Event – 8 LOC;
– Pool – 7 LOC;
– Lane – 7 LOC;
– Average – 7 LOC.

Let us modify the original COCOMO PE formula to consider the estimation of business process modeling effort in hours [2]:

$$PE_s = x_s \cdot H \cdot m \cdot KLOC^n,$$
$$s \in S, S = \{design, implementation, testing, maintenance\},$$

where: s is the process (implemented by some a software system) lifecycle stage; x_s is the coefficient of expenses depending on the process lifecycle stage; S is the set of process lifecycle stages, which includes design, implementation, testing, and maintenance; m and n are the COCOMO model parameters; H is the number of hours per person-months, $H = 152$.

According to IBM's Systems Sciences Institute, the cost to remedy a mistake discovered after product release was four to five times that of one discovered during design, and up to 100 times that of one discovered during maintenance [3].

Hence, the values of x_s depending on the process lifecycle stage are the following [3]:

– Design – 1;

– Implementation – 6.5;

– Testing – 15;

– Maintenance – 100.

Finally, to estimate the Process Cost (PC) based on the calculated using COCOMO model PE metric [6], the following formula is proposed [2]:

$$PC_s = PE_s \cdot W,$$

where W is the process modeling cost per hour, expressed in money measures (e.g. U.S. Dollars, Euro, Turkish Lira, Ukrainian Hryvnia etc.).

The approach based on the previous steps is used as the backbone for the development of the software solution for estimation of business process modeling effort and cost. The software tool for estimation of business process modeling effort and cost uses the 3-layer client-server architecture:

– MySQL as the database management system (DBMS) for the persistence layer;

– Java platform with Servlets for the backend;

– JSP (Java Server Pages), HTML (Hyper Text Markup Language) and CSS (Cascading Style Sheets) for the frontend.

The sample set of BPMN 2.0 business process models used to validate the proposed approach and the software solution for estimating the effort and cost of business process modeling is taken from the public GitHub repository shared by the Camunda company. This dataset of business process models [4] represents the result of BPMN modeling training sessions conducted by Camunda.

The goods dispatch business process model from this collection is demonstrated in Fig. 1.

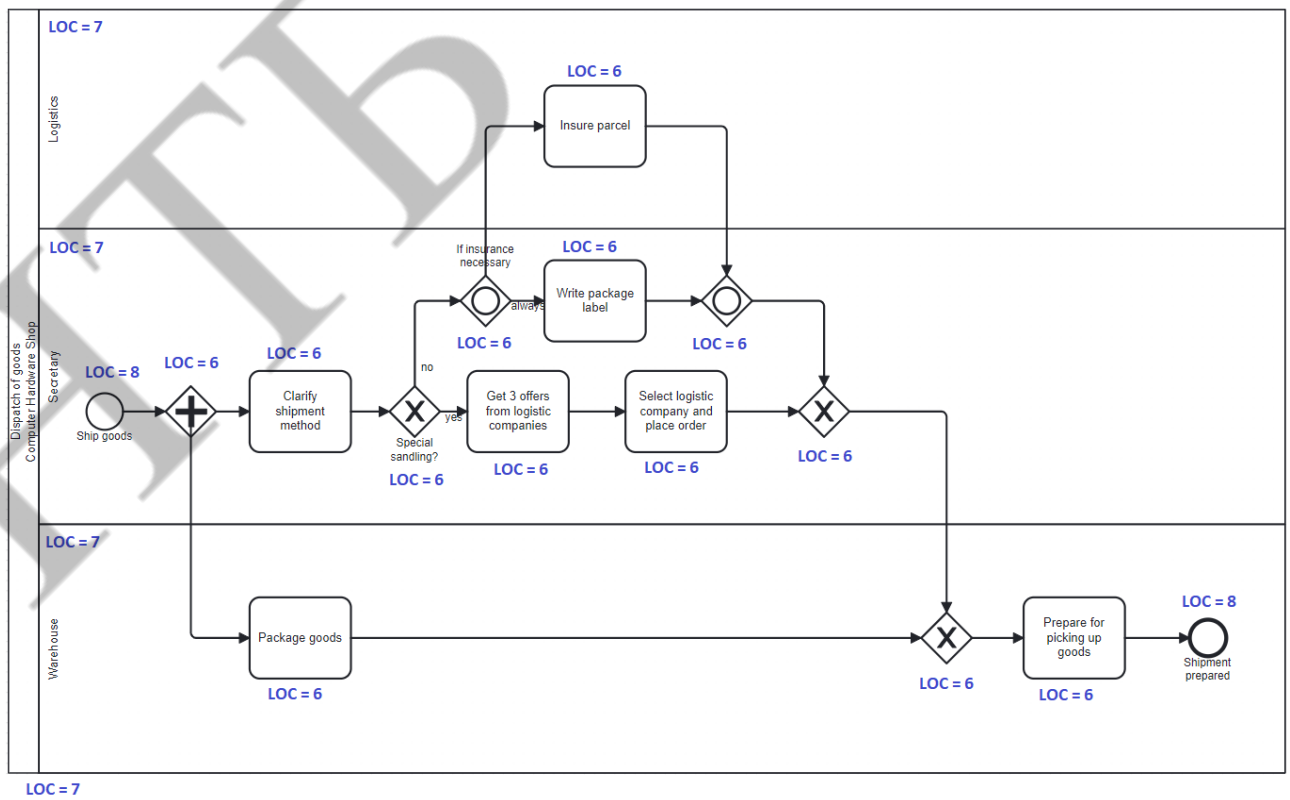

Figure 1 – Goods dispatch process model [4]

Obtained results of effort and cost estimation for the goods dispatch BPMN model (Fig. 1) when considering the design stage ($x_s = 1$) and low complexity ($m = 2.4$, $n = 1.05$) are the following:

$$PE_s = 1 \cdot 152 \cdot 2.4 \cdot \left(\frac{19 \cdot 7}{1000}\right)^{1.05} = 61.96 \text{ peson} - \text{hours},$$
$$PC_s = 61.96 \cdot 45 = 2788.12 \text{ USD}.$$

The values obtained reflect the total effort and cost of business process modeling, including interviews and other techniques for extracting business process information.

Conclusion. The following tasks were completed in this study to solve the problem of business process modeling effort and cost estimation:

1) the approach for estimation of business process modeling effort and cost is proposed;
2) the software implementation of the proposed approach is developed;
3) the software is used to estimate business process modeling effort and cost.

REFERENCES

[1] F. Baumann, A. Milutinovic, and D. Roller, "Software Engineering Inspired Cost Estimation for Process Modelling," Zenodo, Jan. 2016, doi: https://doi.org/10.5281/zenodo.1111791.

[2] Dmytro Orlovskyi and A. Kopp, "An Information Technology for Detection and Fixing Effort Estimation of Business Process Model Structuredness Errors," Springer eBooks, pp. 127–152, Jan. 2022, doi: https://doi.org/10.1007/978-3-031-20834-8_7.

[3] "Defect Prevention: Reducing Costs and Enhancing Quality," iSixSigma, Feb. 26, 2010. Accessed: Sep. 19, 2023. [Online]. Available: https://www.isixsigma.com/industries/software-it/defect-prevention-reducing-costs-and-enhancing-quality/

[4] "BPMN for research," GitHub. Accessed: Sep. 19, 2023. [Online]. Available: https://github.com/camunda/bpmn-for-research.

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SOFTWARE TOOL FOR BPMN DIAGRAMS EVALUATION AGAINST MODELING RULES

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Abstract. *Organizations may enhance their efficiency, minimize mistakes, and improve output quality by ensuring that all business process diagrams adhere to agreed modeling guidelines. The object of study is the process of business process diagrams evaluation against modeling rules. The subject of study is the software solution for business process diagrams evaluation against modeling rules. The goal of study is the improvement of business process diagrams in terms of correspondence to modeling rules by developing a respective software solution.*

Problem statement. Business process modeling is a vital technique of the Business Process Management (BPM) methodology. It facilitates alignment between IT and business by promoting effective communication between business users, including CEOs, managers, and other stakeholders, and IT engineers responsible for developing and maintaining enterprise information systems. Graphical business process models, including Business Process Model and Notation (BPMN) and other notations, capture and analyze current workflows to identify opportunities for improvement. This can be achieved through upgrading existing IT systems or implementing new modules where required, especially for workflows that have not yet been automated. Captured business process models must be clear, well-organized, and free of uncertainties. Without these qualities, it would be impossible to conduct a proper analysis of current enterprise activities and recommend effective ways to improve them. Additionally,