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Research Paper

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In this paper, a discrete simulation model was developed for the certificate of occupancy (CO) for certain buildings issuance process in the Republic of Croatia. The model demonstrates the multistage nature of the process, with site inspections being the most time-consuming stage and a potential bottleneck. The model also shows that senior professional associates have the highest workloads. A what-if analysis was conducted to simulate the failure of the eDozvola system and to demonstrate the significant impact of such an interruption. A cost analysis of the CO issuance process demonstrated the potential for cost savings and efficiency gains through process optimization. Thus, simulation modelling can significantly improve the CO issuance process, resulting in cost reduction, increased efficiency, greater stakeholder satisfaction, and better decision-making.

Key words:
certificate of occupancy, discrete simulations, simulation modelling, what-if analysis

Prethodno priopćenje

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Simulacija procesa izdavanja uporabne dozvole

U ovom radu razvijen je diskretni simulacijski model za proces izdavanja uporabne dozvole za određene građevine u Republici Hrvatskoj. Proces izdavanja uporabne dozvole je složen i odvija se u nekoliko faza, pri čemu najviše vremena oduzima provođenje očevida na licu mjesta, što upućuje na to da bi upravo taj korak mogao predstavljati usko grlo u procesu. Model također pokazuje da viši stručni suradnik ima najveće radno opterećenje. Provedena je što-ako analiza simulirajući kvar u sustavu eDozvola upozoravajući na značajan utjecaj takve smetnje. Također je provedena analiza troškova za proces izdavanja uporabne dozvole koja pokazuje mogućnosti za uštedu troškova i povećanje učinkovitosti optimizacijom procesa. Simulacijsko modeliranje može značajno poboljšati proces izdavanja uporabne dozvole, što rezultira smanjenjem troškova, povećanom učinkovitosti, većim zadovoljstvom dionika i boljim procesom donošenja odluka.

Ključne riječi:
uporabna dozvola, diskretne simulacije, simulacijsko modeliranje, analiza što-ako

1. Introduction

Issuing Certificates of Occupancy (COs) is important for ensuring the safety and compliance of buildings in the Republic of Croatia. This certification plays an important role in protecting public health, safeguarding property rights, streamlining construction processes, and promoting sustainable development. However, the CO issuance process can be complex and stochastic, requiring varying amounts of time, owing to factors such as the complexity of the building, availability of inspectors, system failures, and application backlogs.

Discrete simulation techniques are well suited for modelling such probabilistic processes and gaining insight into the workflow of CO issuance. This study presents a discrete simulation model developed using the Arena simulation program to simulate the CO for certain buildings issuance process. By simulating the process from the arrival of the applicant to the final issuance of the certificate, the model can identify bottlenecks, potential delays, and associated costs. The results clarify that process improvement strategies are required to streamline the CO issuance process and optimise the use of resources.

This approach provides a data-driven basis for decisions and practical implementation, promoting a more efficient and effective system for CO issuance in the Republic of Croatia.

2. Theoretical background and previous research

A simulation is a robust problem-solving tool that is often used in engineering, business, and science to test new designs, predict the behaviour of systems, and optimise process performance. A simulation can be defined as an experiment with a model, that is, it involves recording data about a model. Each output variable is accompanied by a set of individual events during the simulation, which are not meaningful by themselves but are a statistically large sample as a set and provide information about the system [1]. Simulations are usually divided into discrete event simulations (DES), which are suitable for problems in which the variables change in discrete steps over time, and continuous simulations, which are suitable for systems in which the variables change continuously [2–4]. An appropriate simulation method is selected based on the specific problem to be solved. This study focuses on DES.

Discrete simulation models describe in detail the elements of a system, their interactions, and events that change the system state over time [5]. DES can be defined as the modelling of systems in which the state variable changes only at a discrete set of points in time [5]. System behaviour is described using a discontinuous (discrete) method in terms of a sequence of events and activities in the system. The basic elements of discrete simulations are entities, events, activities and process [5]. This method is particularly suitable for analysing queues [6]. Modelling using discrete simulations is intended to provide a detailed description of the system. A special feature of discrete simulations is that the models emulate real systems and processes such that objects from real systems or processes are assigned to the corresponding objects in the simulation model.

Discrete model entities (objects) can be permanent or temporary, and have attributes. Permanent entities (or resources) remain in the model for the entire duration of the simulation, whereas temporary entities pass through the system [7]. Entity attributes describe properties (each entity can have multiple attributes) [6]. Queues form a group of temporary entities that wait for resources to be released. Using these terms, a discrete simulation can be summarised as follows: entities with attributes interact with activities under certain conditions by generating events that change the system state [7]. The duration of the processes and the time of arrival of entities can be unpredictable and vary from case to case. To account for this variability and model the randomness of these events, random variables with different probability distribution functions were used. These functions can be used to represent the distribution of possible values for a random variable, which can be used to simulate the duration of processes and arrival times of entities [5].

The disadvantage of discrete simulations is that considerable time and cost are involved in collecting input data from different data sources to ensure a valid simulation [8].

3. Preliminary research in the field of discrete simulations

The discussion so far strongly indicates that discrete simulations have a wide range of applications in different fields. Kwon et al. (2021) developed a simulation model for supply chain management during the construction of a building with precast concrete elements. They used the Arena program for the simulation and concluded that the model adequately represented the process [9].

Plamenco et al. (2021) conducted a simulation using the Arena program to evaluate the workforce performance during the construction of a slotted concrete wall. The DES model used by Arena could estimate the performance rate of shotcrete wall and was successful in incorporating installation and travel times, which are often neglected in traditional performance analysis methods. Although it is difficult to obtain a standard operating rate for the shotcrete method, it is advantageous to use DES to estimate such rates, as the operating sequences can be broken down into discrete processes. The advantages of DES are evident: it requires less effort and is a reliable method for modelling the conditions of the process [10].

In his Ph.D. thesis, Larsson (2021) investigated various factors affecting productivity and concluded that the description and study of complex production systems (such as construction sites) is possible using discrete simulations. The aim of this research is to increase the knowledge on how DES can be used to systematically analyse the influence of different factors on productivity in the construction of concrete frame structures [11].

Fauth, Malacarne, and Marcher (2022) discussed the lack of digitalisation in building permit authorities. Granting building permits remains a manual and time-consuming process. A prototype BIM-oriented and process-based web application was developed to support building-permit authorities in reviewing building permits. A case study was conducted in South Tyrol (Italy) to test the prototype. The results showed that the prototype was well received and could be used to support building permit authorities; however, more work is needed to improve its usability and functionality [12].

4. Research methodology

The subject of this study was the simulation of the CO for certain buildings issuance process. The model is based on data collected through interviews with local authority staff and observations recorded from the CO issuance process. The interviews provided information on the typical duration of each step in the CO issuance process and the frequency of various events, such as the approval or rejection of the CO application. The observations provided information on the actual duration of individual steps in the approval process and the frequency of delays.

The aim of the simulation was to gain insight into the CO issuance process for buildings, to identify potential problems and delays, and to make recommendations to increase the efficiency of issuing the CO.

The CO is issued to confirm that the building was constructed and completed in accordance with the stage of completion specified in the building permit; that is, the work has been carried out in accordance with the building act issued [13].

The CO for certain buildings is issued in the information system of the Ministry of Physical Planning, Construction and State Assets "eDozvola" (ePermit), as well as other physical planning and construction acts. The eDozvola system has been in operation since 2014 and serves to standardise and ensure the legality of the preparation, adoption, and implementation of procedures based on the Physical Planning Act and Building Act [14].

A CO for a certain building comprises the following parts: a header indicating the issuing authority, the applicant information, a declaration specifying buildings for which the CO is issued, data about the building (external dimensions, number of stories, and accommodation on the building plot), notes on the fulfilment of the basic requirements for the building, a document supporting the issuing of the CO, a note confirming the amount and payment of the administrative fee, an instruction on the right of appeal, and finally, the signature of the official and stamp of the official seal [13]. Further information on the procedure for issuing a CO can be found in the Construction Act (NN 153/13, 20/17, 39/19, 125/19) [15] and in an article by Obradović et al. from 2017 [13]. The process under consideration in this paper is the issuing of the CO for certain buildings.

4.1. Issuing the certificate of occupancy

The process of issuing a CO for certain buildings in the Republic of Croatia is regulated by the Construction Act (NN 153/13, 20/17, 39/19, 125/19) [15]. The process is initiated by submitting an application to the relevant administrative body, which then reviews the application for completeness and enters the necessary information into the eDozvola system. An on-site inspection is then conducted to verify that the construction complied with the existing documentation. If the construction complies, the administrative body prepares a CO, which is then approved and issued to the applicant. The entire process must

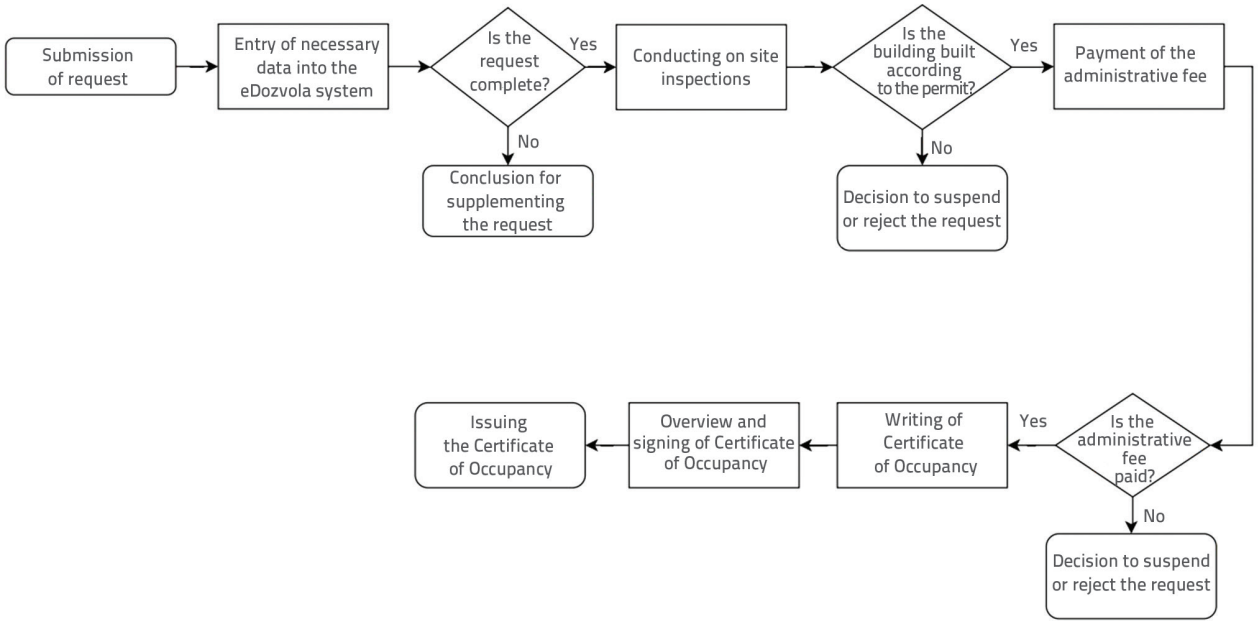

Figure 1. Flowchart for the Certificate of Occupancy for certain buildings process (Source: authors)

be completed within 60 days, although this duration may be extended if there are any errors in the eDozvola system. The Ministry of Physical Planning, Construction and State Assets is responsible for remedying possible errors in the functioning of the eDozvola system. If the construction does not correspond to the approved plans shown in the documentation, a decision is issued to suspend the procedure (if the party withdraws the application) or reject the application (if the party does not want to withdraw the application).

The procedure for issuing a CO for certain buildings in the Republic of Croatia is a multistep process that includes the submission of an application, review of the application, entry of data into the eDozvola system, on-site inspection, preparation of inspection reports, comparison of the existing condition of the building with the existing documentation, payment of the administrative fee, submission of proof of payment, and preparation, review, and issuance of the CO. The procedure for issuing the CO is shown in Figure 1.

4.2. Input data and process characteristics for simulation modelling

The CO issuance process involves three key officials: clerks, senior professional associates (SPA), and senior advisors. The clerk handles the initial application and data entry, and the SPA manages the administrative procedures, including on-site inspections, fee collection, and decision making. The senior advisor reviews and signs the CO.

The workload varies between these roles, with SPA undertaking the most demanding tasks, followed by clerks and senior advisors. Their salaries are also determined by different coefficients depending on the complexity of their tasks and their years of experience [16, 17]. The salary base is set at EUR 497.71 and the corresponding coefficients are listed in Table 1. Considering a 20-workday month and an 8-hour working day, this results in a total of 160 work hours per month.

The arrival of clients, that is, the applicants for CO in the process, follows an exponential distribution. All other required processing times (e.g. submission of request and entering data into the eDozvola system, reviewing the application, conducting on-site inspections, and developing solution) were determined based on empirical data using a triangular distribution. The procedure durations are summarised in Table 2.

The action mode was chosen for three different processes associated with issuing a CO. This means that the entity (application) awaits its turn until all three resources (employees) are available. When it is the entity's turn, it requests the available resource (seizes), interrupts the process for a certain period of time (delay), and then releases the resource for another task [18].

The most critical decisions in the CO issuance process in which the decision module is used are as follows. Determining the completeness of the application: the application can be complete (all the required documents are attached) or incomplete. If it is incomplete, a notification is sent to complete the application. Verification of compliance with the building permit: If the building complies with the attached building permit, the process moves a step closer to the issuing of the CO. Otherwise, the application is rejected or the procedure is suspended. Ensuring payment of the administrative fee: The CO can be issued if the fee is paid, and is otherwise refused.

These important decisions are made using a decision module that evaluates the application based on certain criteria and determines the appropriate course of action.

The simulation was conducted over a replication period of 20 days, which corresponded to the average number of working days per month. We assume that an application for a CO is submitted daily. The hours per day were set to 8, and the base time units were minutes. Errors and delays were allowed in the simulation to reflect the potential of such occurrences in any software or application. The Ministry of Physical Planning, Construction and State Assets was responsible for correcting system errors. This process usually requires a few hours or a day to complete.

Table 1. Position, salary calculation coefficient and salary amount for analysed employees (Source: table structured by authors according to [16,17])

Category of employees	Workplace	Salary calculation coefficient	Salary [EUR/h]
Category III	Clerk	1.51	4.67
Category II	Senior professional associate	2.06	6.37
Category II	Senior advisor	2.60	8.04

Table 2. Procedure durations in the Certificate of Occupancy issuance process (Source: authors)

Procedure	Minimal value [min]	Most common value [min]	Maximal value [min]
Entry of data into the system	30	45	240
Conducting on-site inspection	45	90	180
Administrative fee letter	30	90	240
Creation of decision - certificate of occupancy	30	60	240
Overview and signature of certificate of occupancy	15	30	120

5. Research results

5.1. Description of the simulation model

A detailed description of the simulation model was presented in the previous section. The simulation model created using Arena is shown in Fig. 2. The simulation aimed to optimise costs while maintaining acceptable levels of queue length, waiting times, and employee utilisation.

The simulation model shown in Figure 2 consists of several modules to effectively capture the complexity of the observed process. The breakdown of the modules is as follows.

The initial modules defines the entities in the process, and in this paper, these are the requests for issuance of COs, as well as their frequency and time distribution. Five modules simulated various stages of processing within the system. These stages correspond to various steps or tasks involved in processing and assessment of the CO application. Three modules that deal with the decision-making processes within the simulation are compliance assessments, document reviews, and decisions influencing the course of the CO issuance process. Four modules are responsible for managing the closure or disposal of units within the system, including the module concerning the creation of a CO once all requirements have been met.

The entity that assumes centre stage throughout the simulation is the application for a CO. As the simulation progresses, this application progresses towards the issuance of a CO, which depends on the fulfilment of all the requirements necessary for issuing the CO for certain buildings.

This modular breakdown allows for a comprehensive representation of the entire process of issuing a CO, including the creation, processing, decision-making, and finalisation phases. A discrete simulation approach enables a dynamic and detailed examination of how these modules interact and influences the overall outcomes of the CO issuance process.

5.2. Simulation results

A comprehensive simulation of the CO issuance process provides important insights into the efficiency and cost-

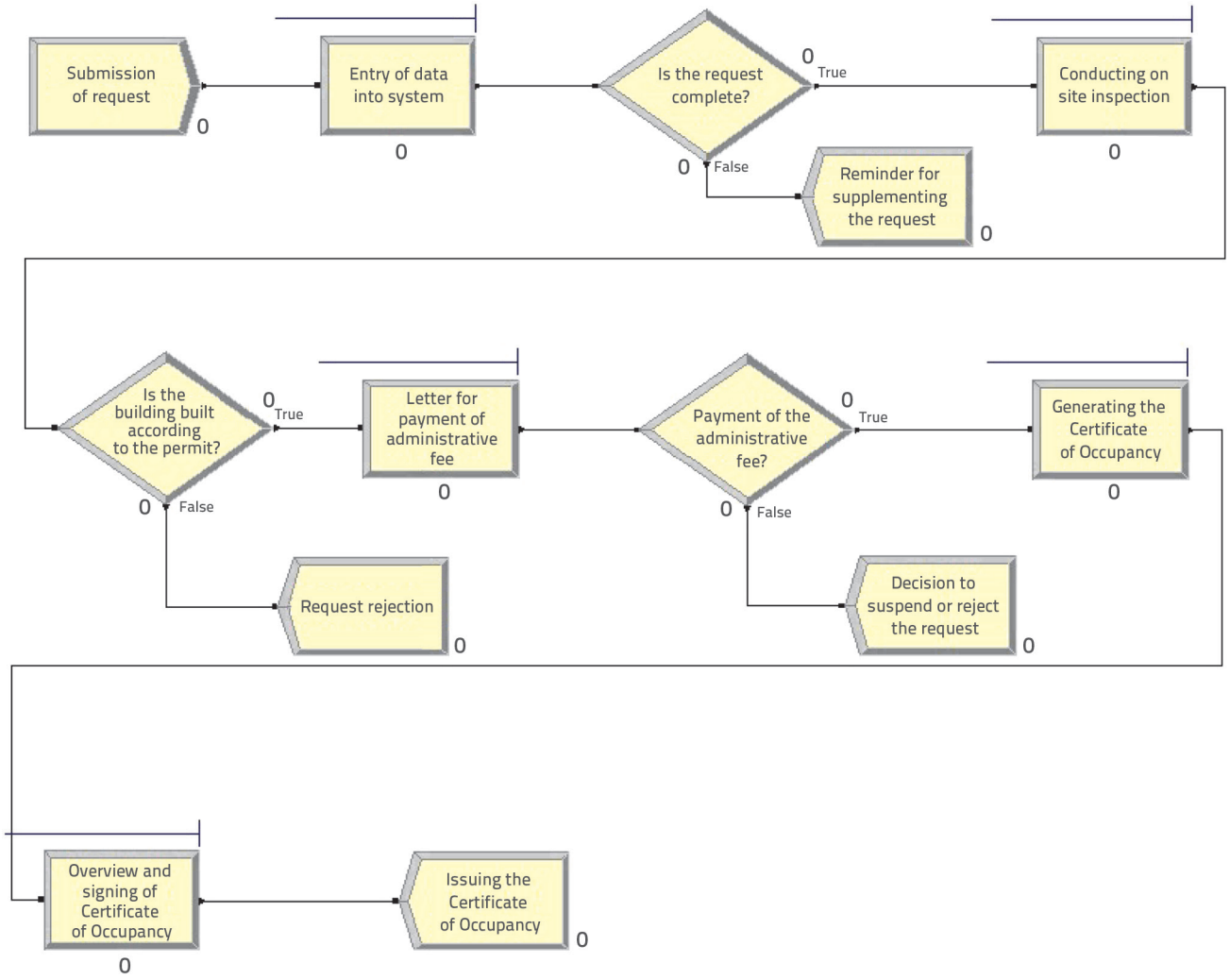

Figure 2. Presentation of simulation model in Arena program (Source: authors' work in Arena program)

effectiveness of current workflows. The results highlight the need for optimisation and streamlining of the process to minimise associated costs.

SPA played the most active role, accounting for over 47 % of total working time. Clerks play an important role, with approximately 24 % of working time. The senior advisor, who is primarily responsible for reviewing and signing COs, takes up the least working time, at approximately 7 %.

On average, it takes 465.55 minutes to process a CO application, illustrating the lengthy nature of this process. The average waiting times for the individual processes vary: Data entry takes 16.37 minutes, on-site verification takes 27.76 minutes, preparing the letter for payment of the administrative fee takes 35.73 minutes, drafting the CO takes 38.84 minutes and the overview and signing of the CO takes 0.13 minutes. The maximum waiting times are significantly higher: the data entry takes 191.83 minutes, the on-site inspection 222.68 minutes, the preparation of the letter 287.07 minutes, the preparation of the CO 262.82 minutes and the overview and signing of the CO 9.93 minutes.

The total cost of processing the amount to EUR 3,047.00. The total cost of the use of resources amounted to EUR 742.00, whereas the total cost of unused resources amounted to EUR 2,304.00. This illustrates the less efficiency of the current process and the long idle time of resources. The average cost per processed CO was EUR 37.69. The cost per working time for each resource is as follows: clerk, EUR 179.40; SPA, EUR 476.53; and senior advisor, EUR 86.54.

The results highlight the importance of process optimisation to increase efficiency, reduce waiting times, and minimise associated costs. Streamlining workflows and addressing resource utilisation issues are likely to contribute to more effective and cost-efficient processes for issuing CO.

To improve the efficiency and cost-effectiveness of the CO issuance process, policymakers should implement the following recommendations.

Streamline the process to minimise wait times and maximise resource utilisation; that is, streamline the process by identifying and eliminating unnecessary steps, implementing measures to expedite data entry and onsite inspections, and exploring opportunities to automate or streamline certain tasks. It can also allocate workloads to resources according to their respective capacities, train staff to multitask to increase flexibility, and implement flexible work schedules to accommodate peak times. Optimise resource allocation to ensure optimal utilisation, identify the potential for cost reduction through automation or streamlining, implement strategies to reduce delays, and expedite CO issuance. By implementing these recommendations, the current process can significantly improve the efficiency, cost-effectiveness, and overall quality of issuing certificates of origin by streamlining operations and optimising the use of resources.

In this what-if analysis, for the simulation model considered and the process of issuing the Certificate of Occupancy, it was assumed that there was an error in the functioning of the eDozvola system and that it took 12 h (720 min) to reach the most frequent value of (c) in the triangular distribution. This scenario, which is triggered by a real incident, is considered realistic and plausible.

All other parameters of the process remain the same; only the abovementioned parameters are changed such that for this process (design of the solution), the time in the triangular distribution is a = 600 min, c = 720 min, and b = 840 min. Changes were made after the simulation.

The average cost of processing one entity, which amounted to EUR 37.69, has now increased to EUR 70.77, 19.80 requests have now entered the process during the simulation, and 15.80 requests (COs) have been issued.

6. Discussion

SPA have the highest involvement in issuing COs, accounting for over 47 % of the workload. This suggests that the SPA are quite burdened and can benefit from distributing some of its workload to other staff members. Clerks also played an important role in issuing COs, accounting for approximately 24 % of the workload. However, senior advisors' involvement was minimal, accounting for only 7 % of the workload. This suggests that senior advisors' expertise is not fully utilised and that their time could be better spent on other tasks. The initial process analysis revealed that SPA have the highest involvement in issuing COs because they have the specialised skills and knowledge required for this process. The clerk is responsible for administrative tasks, whereas the senior advisor is responsible for monitoring and approval.

The what-if analysis shows that the process of issuing COs is particularly prone to delays if there are problems with the eDozvola system. A queue of 3.09 CO applications can accumulate, and the average cost of processing an application increases by 87 %.

To improve the efficiency and effectiveness of the CO issuance process, the following recommendations are made: 1. Ensure that staff are assigned tasks according to their skills, expertise, and availability to maximise efficiency. 2. Minimise the impact of system downtime, that is, establish clear protocols for dealing with system issues and ensure that at least one person from the eDozvola system support team is available at all times during working hours. 3. Identify and eliminate unnecessary steps in the CO issuance process to reduce overall processing time. 4. In particular, automate repetitive tasks such as preparing letters to provide free time for value-adding activities.

It is important to emphasise that only the CO issuance process for certain buildings was modelled in this study. However, the Administrative Department performs many different tasks and issues several types of building documents, which are not considered in this study.

7. Conclusion

A discrete simulation model was developed to analyse the CO issuance process for certain buildings in the Administrative Department. The simulation model was created using the simulation program Arena, a robust tool for modelling stochastic processes such as the process of issuing CO. The model includes three key roles involved in the CO issuance process: clerks, SPA, and senior advisors. The data for the model were derived from both published literature and empirical observations to ensure a comprehensive representation of the real-world process. The simulation results confirmed the initial assumption that the SPA have the highest involvement, handling approximately 47 % of the workload. Clerks and senior advisors play a supporting role and contribute approximately 24 % and 7 % of the workload, respectively.

A what-if analysis was conducted to investigate the impact of potential system disruptions, particularly issues with the eDozvola system used to issue the COs. Errors in the operation of an eDozvola system cannot be predicted. During work in the eDozvola system, there is a possibility that the system will not respond, which blocks further work. Thus, it is necessary to contact the Ministry to eliminate failures. Additionally, it is possible for an employee to make unintentional mistakes while working on the eDozvola system. The results revealed that system failure can lead to significant delays and higher costs, with an average increase in processing cost of 87 % and a queue of 3.09 CO applications. It was observed that a small failure in the operation of the eDozvola system can have a significant impact.

The research results underline the importance of system stability and resource optimisation for an efficient CO issuance process. Further research could benefit from including other processes within administrative departments, such as building permit issuance, to gain a more comprehensive understanding of resource utilisation. Measuring the actual task duration would further refine the simulation model and lead to more accurate predictions.

In addition, it should be noted that every computer program, system, or application is subject to failures and operating difficulties, and it is necessary to strive for the eDozvola system to have as few failures as possible.

Further, although simulation models are powerful tools, they still represent real-world processes and should be interpreted with caution. Familiarity with the modelling process is essential to ensure that the model accurately reflects the actual dynamics. Overall, the simulation model provides valuable insights into the CO for certain buildings issuance process and highlights areas for improvement. By addressing resource bottlenecks and system stability issues, administrative departments can increase efficiency, reduce costs, and improve overall service delivery.

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