USING CMMN MODEL FOR SOFTWARE SYSTEM PROJECT SIMULATION

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Abstract

Software systems (SS) project failure has been a recurring problem for decades. One of the project success factors is the appropriately chosen project management methodology and its adaption to the project type, company, and employees. Although some methods have been proposed to address this problem, the number of failed projects shows that the problem is still relevant. Therefore, a new and more efficient solution is needed. This paper proposes a new approach for choosing and adopting a project management methodology to a particular context (i.e., the project type, company, and its employee, etc.). It is based on dynamic CMMN (case management model and notation) SS project management process modelling and simulation. The proposed approach is evaluated with an industry case study. The obtained results showed that the proposed approach is implementable and can be used for SS project simulation.

Keywords: CMMN, dynamic business process, simulation, project management

1. Introduction

Software systems (SS) project failure has been a recurring problem for decades [28]. This also can be seen from the Chaos Report [26], which indicates that the number of successful projects increases slightly from year to year [4]. As stated in [4,19], technical and methodological aspects are becoming less critical in IT project execution, while soft management and planning mechanisms [11] and the recognition of the impact on the users being of vital importance [11]. Every project has many components - people working in the project team, state restrictions, business rules, and various other impossible planning factors [1]. Therefore, an appropriately chosen project management and planning methodology and adaption to the client role and project type become the project's main success factors [4,19,22,27,5].

Nowadays, there are many project management methodologies [3], among which the most common are the following: Waterfall, Agile, Scrum, Kanban, Scrumban, eXtreme programming (XP), Adaptive project framework (APF), Lean, Critical path, Critical chain, New product introduction (NPI), Package enabled reengineering (REP), Outcome mapping, Six Sigma, PMI's PMBOK, PRINCE2, Rapid application development (RAD). However, the majority of those methodologies have their disadvantages.

Agile requires active user involvement and close collaboration with the project team throughout the software development cycle. However, in practice, these principles are very demanding on the user representative time and require a big commitment for the duration of the project. Therefore, we need flexible project management and planning adaption according to the client's needs.

Given the need to adapt the methodology itself to the client and not just its activities, it is suggested to use a case management approach. Case management is a business process technology that does not use a management flow process to describe it. Instead, it gives employees access to all the information relevant to a particular case and the freedom to

make decisions. In a case management system, employees are responsible for the business goal, and they use the system as a tool to achieve that goal. Case management depends more on the employee than on the control process. Thus, by adapting the CMMN and assessing a future project's scope, resources, and risks, the project failure probability can be reduced [13].

Most of the existing project management and planning methodologies are based on traditional statistical and mathematical models [10], like regression and interpolation, which cannot solve complex and nonlinear tasks, as software project management and planning. The main principle challenges [10] are as the following: 1) the relationships between software output metrics and contributing factors exhibit strong complex nonlinear characteristics; 2) measurement of software metrics are often imprecise and uncertain; 3) there is difficulty in utilizing both expert knowledge and numerical project data in one model. Simulation in various complex business processes is already being applied by organizations seeking to optimize long-established workflows. Business process simulation allows process executors to see the complete picture of the simulated process, i.e., the interdependencies of the activities, the conditions for the execution of activities, and possible crashes or downtime locations. As project management is a knowledge-intensive and dynamic process, business process simulation can help us plan the project and reduce its failure.

In this paper, we analyse the following research questions: 1) What uncertainties affect the dynamism of business process management? 2) What are the possibilities of CMMN to model dynamic processes? What tools support CMMN and what are their capabilities? 3) What simulation techniques would allow simulating human work? What are the possibilities of these methods?

This paper proposes a new approach for choosing and adopting a project management methodology to a particular context (i.e., the project type, company, employee, etc.) based on dynamic CMMN (case management model and notation) SS project management process modelling and simulation.

Our main scientific contribution and advantages of this paper are as follows. The proposed new CMMN project management approach allows us precisely forecast project management and its resources, finance budget, course of tasks.

The work presents a logical commitment utilizing setting histories to gather the suggestion of dangers to unused ventures. This paper's primary commitment is to utilize closeness examination of venture histories to suggest risks related to the ventures in execution.

The rest of this paper is organized as follows. Section 2 reviews the literature on project management. Section 3 describes the approach of this research. Section 4 presents the results of an experimental study by using project management modelling and simulation. Finally, Section 5 concludes the paper.

2. Related works

A project is a time-bound attempt to create a unique product, service, or result [24]. This time constraint means that a project always has a defined start point and end. However, the result of each project is unique. Although the project's subject area and scope may be remarkably similar or even the same, the product will always have its exclusive characteristics, i.e., different project locations, different stakeholders, or conditions under which the project took place. In turn, project management is applying knowledge, skills, tools, and methods to conduct project activities to meet the project's requirements. All project management is carried out by properly adapting and integrating project management processes, which are divided into five process groups [24]: 1) Initiating; 2) Planning; 3) Executing; 4) Monitoring and Controlling; and 5) Closing.

There are already suggested few methods in related works that could help improve project management in various organizations. For example, the Constructive Cost Model (COCOMO) helps to estimate a software cost, quality, analyse risk, etc. [23]. It was built based on 63 software projects [23]. Anyway, COCOMO has disadvantages, as ignoring

requirements and documentations, hardware issues, personnel turnovers levels, and is dependent on the amount of time spent in each phase [12]. Therefore, different model extensions are proposed, like COCOMO-Fuzzy [10], which applies a neuro-fuzzy approach to carry some of the desirable features of a neuro-fuzzy approach, such as learning ability and good interpretability, while maintaining the merits of the COCOMO model. The model deals effectively with imprecise and uncertain input and enhances the reliability of software cost estimates. In addition, it allows input to have continuous rating values and linguistic values, thus avoiding similar projects having high different estimated costs [10].

Another famous simulation method is Monte Carlo [20], which relies on repeated random sampling and statistical analysis to compute the results. This method is considered appropriate for the what-if analysis [20]. In addition, it is a direct method for performing both simulation and integration [6]. The main disadvantage of the traditional Monte Carlo method is that it is suitable for static data only, i.e., it is not suitable for run-time adaptations during simulation. Moreover, it is difficult to conduct large-scale moves in Monte Carlo [7]. The Monte Carlo method also is integrated with fuzzy logic [2]. Some authors [2] have proposed a method that provides a better measure of uncertainty than the existing methods (i.e., unlike the traditional risk analysis method). This approach considers both variability and uncertainty of information into risk calculation. Instead of a single risk value, this approach provides an interval value of risk values for a given percentile of risk.

Authors of [9] suggest using the Integrated Business IT Impact Simulation (IntBIIS) approach to adequately reflect the mutual impact between business processes (BP) and information systems (IS) in simulation. This approach is implemented by extending the Palladio tool chain with BP simulation concepts [9]. IntBIIS predicts the impact of an IS design and BP performance. The main disadvantage of the suggested approach is that a human factor (like, stress level, motivation, experience, etc.) is not considered. Also, this method is more suitable for BP simulation, but not a project management process, which has more various sub-processes.

The authors of [8] have mentioned that there is no standard model for BP simulation. Existing approaches have their advantages and disadvantages, some of which are presented above. Moreover, there are difficulties in integrating the analysed models, because, as authors of [8] state, they are not described clearly enough. Therefore, in this paper, we propose a new CMMN-based model for SS project simulation.

3. On CMMN model for software system project simulation

3.1. CMMN

CMMN is designed to capture common elements used by case management of the same product. CMMN is known for its adaptive case management, which assists in decision-making by making suggestions and keeping people in the manager position. The case model is focused on real and rapidly changing information and relationships, while traditional business processes are focused on pre-defined sequences of activities [16]. CMMN is commonly used to model dynamic processes, and more and more tools are now emerging that allow models to be run and integrated with other tools. The case model shows all the tasks and their execution parameters, which shows that the tasks can be performed inconsistently - some tasks can be started during the execution of other tasks, if there are suitable free resources in the same time interval [14]. One of the main advantages of the CMMN is that this notation provides an opportunity to illustrate discrete events, thus allowing case handlers to decide for themselves whether a task is relevant to the execution process and whether it will be executed [15]. As early as 2013, there was talk that CMMN could be a suitable opportunity to identify and model dynamic processes. CMMN proposes to move away from traditional process flow modelling and start using task sets that can be started dynamically once the whole process is started [25].

3.2. The software project model

Project management is applying knowledge, skills, tools, and methods to carry out project

activities to meet the project's requirements. Project management is carried out through the proper application and integration of project management processes, which are divided into five process groups:

- Initiation - This process group consists of processes performed to define a new project or a new phase of an existing project. At this stage of the project, the scope and financial resources are defined, the project manager is assigned, and the work sample is defined. The main goal of this process group is to reconcile the expectations of stakeholders regarding the purpose of the project, to give them access to the scope and objectives of the project. The processes of this help define the project's vision - what is needed to make it happen.
- Planning - The planning process group consists of the processes carried out to determine the total amount of resources, specify the objectives and develop the course of action required to achieve the objectives. Planning processes create a preliminary project management plan and project documents that will be used to implement the project. Due to the complex nature of project management, it may be necessary to use repetitive feedback loops to allow for additional planning analyses.
- Execution - The group of executive processes consists of those processes performed to perform the specific work defined in the project management plan to meet the specifications of the project requirements.
- Monitoring and control - The monitoring and control process group consists of those needed to monitor and review the progress and results of the project. The main advantage of this process group is that project execution is measured and analysed at regular intervals, so it is appropriate to identify deviations from the project execution plan.
- Closure - The closure process group consists of those processes that are performed to complete all project activities. This process group checks that the defined processes are completed in all closed process groups, formally determining that the project or a specific phase of the project is completed and closed [18].

3.3. Requirements for software system project model

Based on the related works, the following requirements for the developed project management CMMN model are defined:

1) The model shall provide the option to select or define new management sub-processes required for a new project.
2) The model shall provide the possibility to add or remove sub-processes to/from a project dynamically.
3) The model shall be able to define project tasks, roles, participants, and distribute the defined tasks to different participants and roles.
4) The model shall be suitable to specify the specifics of the project domain area.
5) The developed model shall be open source and in an environment that can be accessed by roles.
6) The developed model shall be suitable for the average IT skills users.
7) The model shall be valid and conform to the CMMN notation.
8) The model shall be able to change the course of the process.
9) The model shall be able to monitor the progress of the process.
10) The model shall be able to analyse the progress of the process.

3.4. The proposed approach

The CMMN model for software system project simulation is developed to depict all tasks relevant to project management and tasks distributed according to project management stages (Fig. 1).

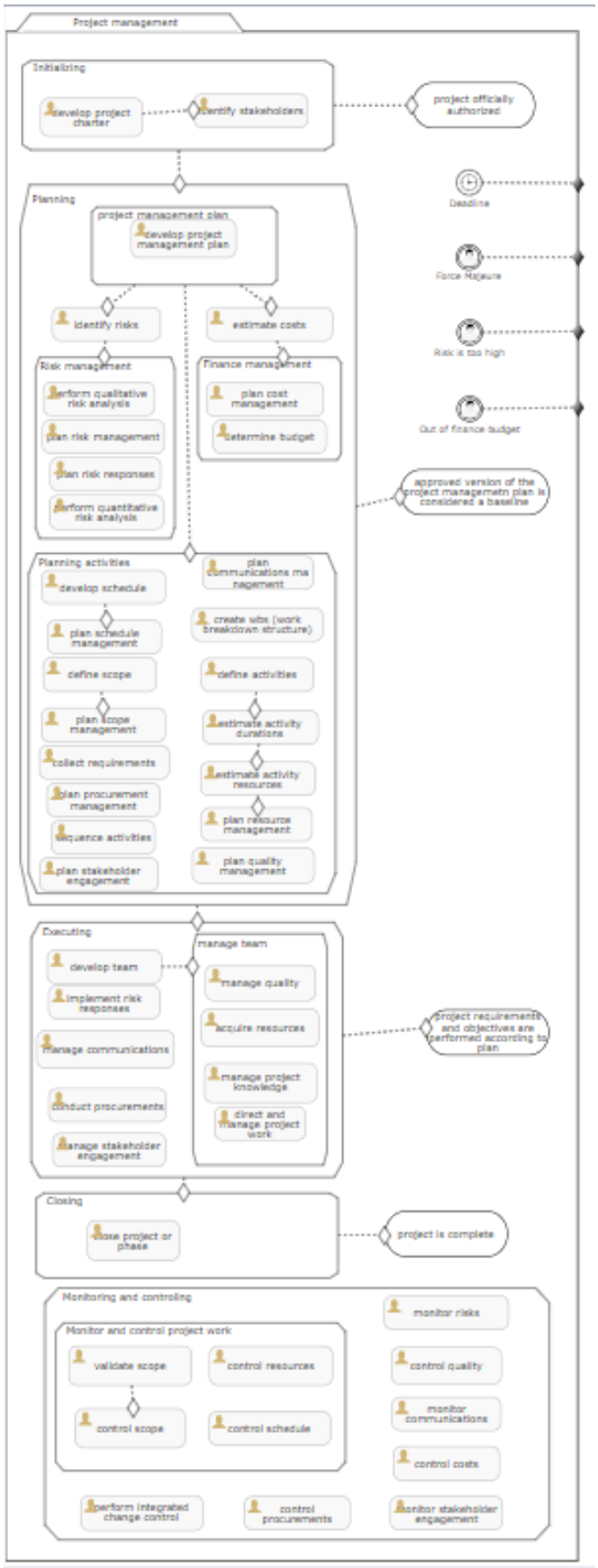

Fig. 1. The CMMN model for project management

In the business case enforcement system, the main resource is the IS development project model, which is developed according to CMMN requirements and notations. It was

developed and has input parameters from task consistency and dependency analysis, role analysis, and task time estimates. A business case simulation tool is a tool that simulates a real project case with selected input data. The simulation tool consists of three separate modules: simulation scenario specification module, simulation scenario execution module, report generation module In report generation module simulation scenario configurations, historical data may be useful in the future to evaluate performance or progress based on specific data, simulation execution data, and report templates. The input data of the business case simulator tool is the specifications of the tasks and resources. The more accurate and detailed these specifications are, the more accurate the input data will be and the more consistent the simulation results will be with the model. Output is a case execution report generated according to report templates, according to the needs of the business or project team.

Using the proposed CMMN model for project management, the SS project modelling and simulation is performed at the initial state of SS project management, when user's needs are defined. Those user's needs are used to define initial variables for the proposed CMMN model input. After the successful verification of all input data, the simulation can start. The accuracy of the simulation results depends on the level of detail and accuracy of the initial data. The obtained results show the project's potential risks, like places of possible delays, working outages, places where resources are not fully utilized, etc. Thus, the analysis of the simulation results is important as it identifies problems and possible future challenges of the project. Based on the analysis of the obtained results, new project management plan can be developed and simulated again. Plan refinement and simulation are performed as many times as possible until a suitable plan meets the user's needs.

If necessary, project simulation can be done during the project process. In most cases, it is necessary if some unpredictable changes, as user's needs change, etc., occur.

4. Implementation of the proposed model

4.1. Implementation architecture

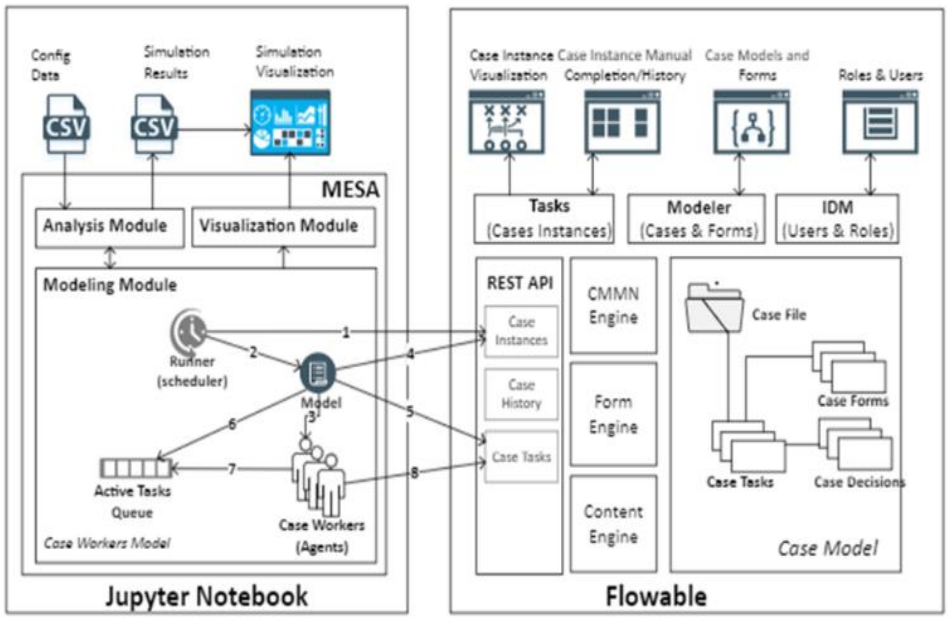

Fig. 2. The architecture of a simulation model for project management.

The proposed CMMN model for SS project simulation was implemented into the prototype using the Python programming language (https://www.python.org/) with the Mesa plugin (https://mesa.readthedocs.io/en/stable/) (see Fig. 2). Mesa is used to simulate the developed CMMN model. For the proposed CMMN model implementation, we have used Flowable (https://flowable.com/). Requests from Mesa to Flowable REST API are sent to

get input data, which defines a sequence of project activities, their duration, and constraints in (.csv) format. The output data is saved in the electronic spreadsheet tool format (.csv) and unique during each simulation. The choice of the Python language was based on its advantages. For example, as a dynamic programming language, Python is widely used in many fields. From developers' side, various language features affect the programming experience. Researchers affect the difficulty of developing tasks such as bug finding and compilation [17].

An example of the input data is presented in Table 1. First, the order of tasks in project management must be listed that it would be clear which task has higher priority and must be done in an earlier stage of the process. An estimation means how much agent resources in a particular role need to be taken to make the task done. The role is assigned to the task means that this task can be done only by this role.

Table 1. Input data example.

Name	Order	Estimation	Role
develop project charter	1	2	project
identify stakeholders	1	1	stakeholder
develop project management plan	1	4	project
plan scope management	7	2	project
collect requirements	7	3	analyst
define scope	5	1	project

Also, the role-agent mapping table is passed as the input (see Table 2). The second input file is provided a list of agents and its number. Each agent has its role, which means that this agent can do only those tasks assigned to his role (from the Table 1).

Table 2. The role-agent mapping table example.

Name	Role
Agent 1	Analyst
Agent 2	Stakeholder
Agent 3	Quality
Agent 4	Communication
Agent 5	Finance
Agent 6	Project
Agent 7	Risk
Agent 8	Hr

4.2. Data for the experiment

For the experimentation in this study, we have used randomly generated (based on theoretical description of SS projects management tasks [21] and described practical experiences [21]) input data. Execution of the entire project management involves many different roles in the company between which tasks are divided at different stages. Because of the case model that shows which tasks and stages can be started dynamically and which can be started consistently, the distribution of tasks between roles can allow for maximum optimization of project management, execution time and methodology. The main project management roles were detailed below: project manager, stakeholder, analyst, finance expert, human resource expert, quality assurance, communication expert, risk manager. All project management tasks and roles were mapped between them to assign all project management activities to appropriate role.

During to experiment, the input data had to be examined and systematized. To simulate the CMMN model of project management it is important to identify the execution time for each task. It is impossible to assess precisely and in detail the tasks of each project implementation activity as it strongly depends on the subject area in which the project takes place. Each subject has it own specifics which are relevant only to specific aspects and this has a direct dependence on the time of tasks execution.

All tasks of the project management process are divided into 5 stages of project management: initiating, planning, execution, monitor and control, and closure. Each task

is performed consistently or dynamically within the project phase, except for monitor and control. This phase and the tasks in it start with the first phase of project management and end with the last phase of project management. This phase with the tasks assigned to it is directly dependent on the execution of the other phases – if one task is delayed and the phase is completed later than planned, the monitor and control phase is extended by the same amount of time.

All the agents involved in the simulation are brought together and assigned roles, according to which project management tasks can be assigned. To successfully complete a process simulation, it is necessary to have all roles as not performing a particular task does not allow to complete the whole case simulation.

The simulation also includes the priorities for each task, the estimated execution times and the role that the agent or agents will be able to perform the task. Agents with different roles can also perform the same tasks depending on their experience or competence. According to the agent is it also possible to reduce or increase the scheduled execution time of the task. It was changed and updated during the simulation, but the structure is kept the same. The task and role data in the input data document was described in the same way as it is saved in the model builder itself by ID value.

5. Results

The main result of the proposed CMMN model for SS project simulation using the developed prototype is presented in Fig. 3.

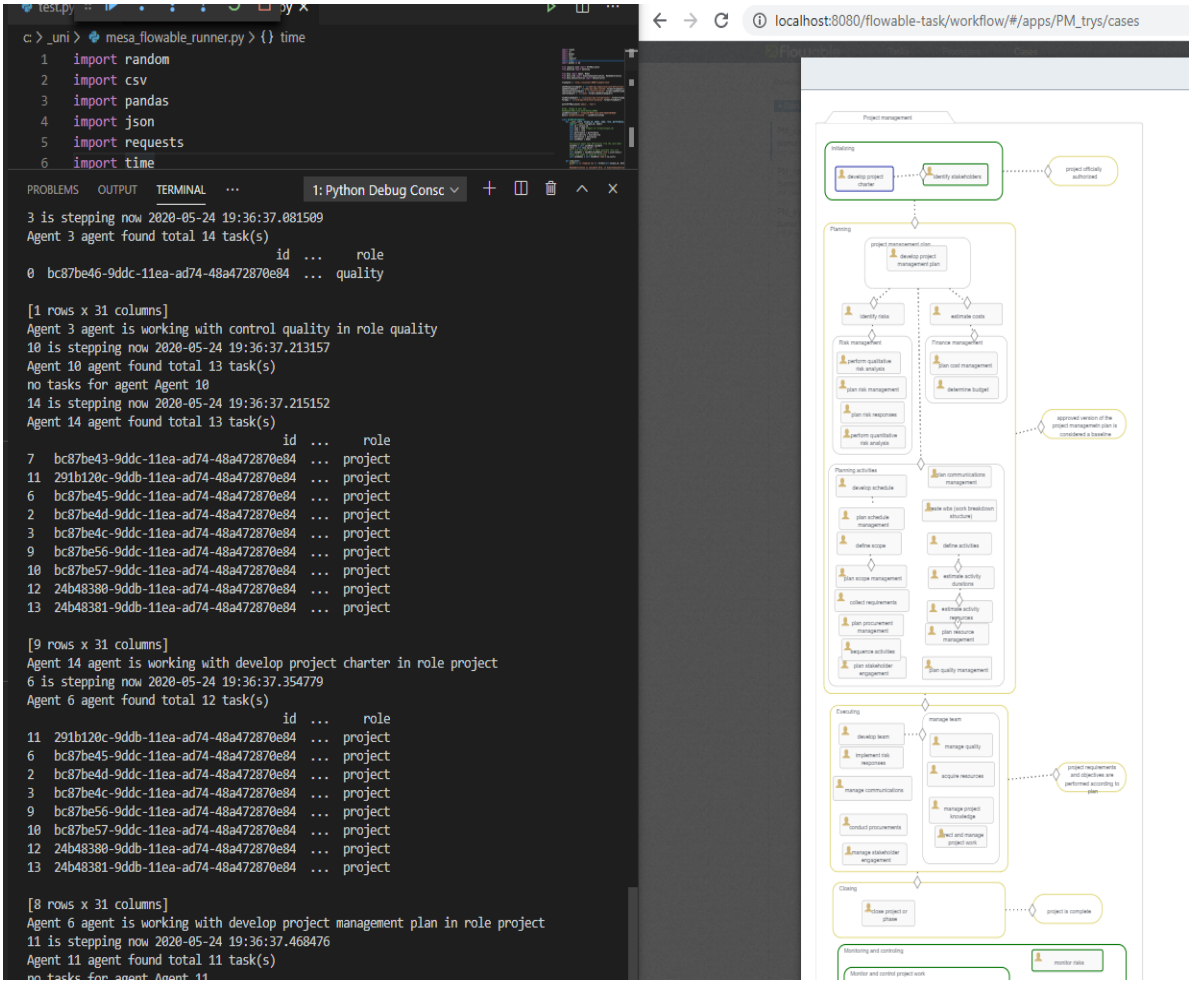

Fig. 3. Simulation of CMMN project management model.

During each iteration, all agents are transitioned to what project tasks they can currently work on. If no active tasks are found for the respective agent during the iteration, a message

is displayed, and the agent waits for the next iteration.

During the simulation, we can see the event log entries (Fig. 3), which show the entries for each iteration. It is possible to monitor how many and which tasks were found during the iteration of a particular agent with the role assigned to it, which task was started, and agents that did not find any active tasks during the iteration.

Results of simulation output data is saved in electronic spreadsheet format: number of iterations, create time, priority, task, agent, estimated time, actual time. The number of stored output data directly depends on the input data. The simulation output data shows the number of iterations which agent performed the specific task, when it was started, the estimated time for the task and the actual time the task was performed.

During the experimental study various parameter related to project management can be calculated according to four aspects as the following:

1. Non-prioritized tasks / resources for all roles by one.
2. Non-prioritized tasks / resources for all roles by two.
3. Prioritized tasks / resources for all roles by one.
4. Prioritize tasks / resources for all roles by two

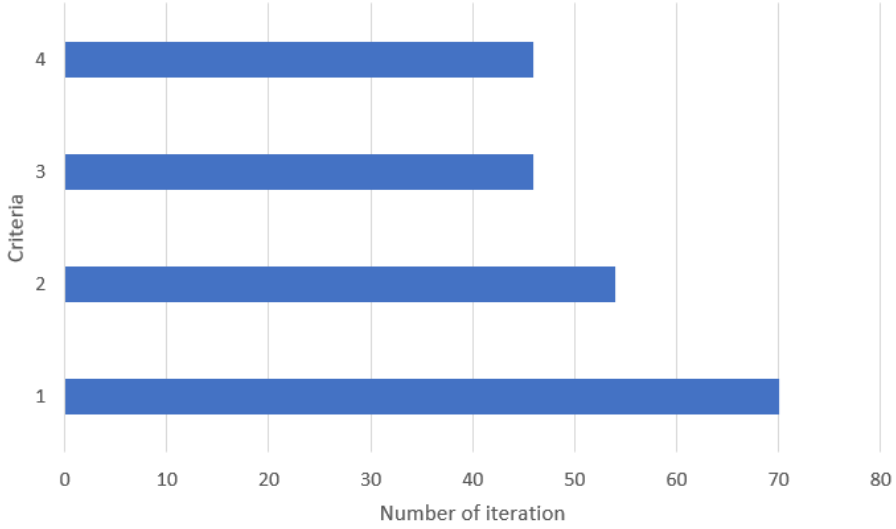

Fig. 4. Number of iterations.

The obtained results showed that the least iterations occur when the project tasks are prioritized. In this case, the agents primarily perform only the most important tasks, thus moving to less important ones and those whose performance do not affect the performance of other tasks.

The results are obtained from the log entries of the simulation events are presented in Fig. 5. During the simulation, records are stored at the time of each iterations to which agent the task is assigned, and which agent did not find the active tasks assigned to it during this iteration. Only event that did not find active tasks for a particular agent were selected from this event log. From these records after defining the roles of agent data was prepared on the extent to which role did not have active task in the project implementation process.

It can be noticed that the roles of the project manager, analyst and risk manager have the least downtime during the iterations, divided according to the roles. Most downtime is observed between stakeholder, tester, and human resource manager. It can be concluded that some roles in project management are key ant more employee with these competencies could be considered to the project, by analogy – some project roles do not perform as many tasks in project management and their resources can be reduces or divided through different projects.

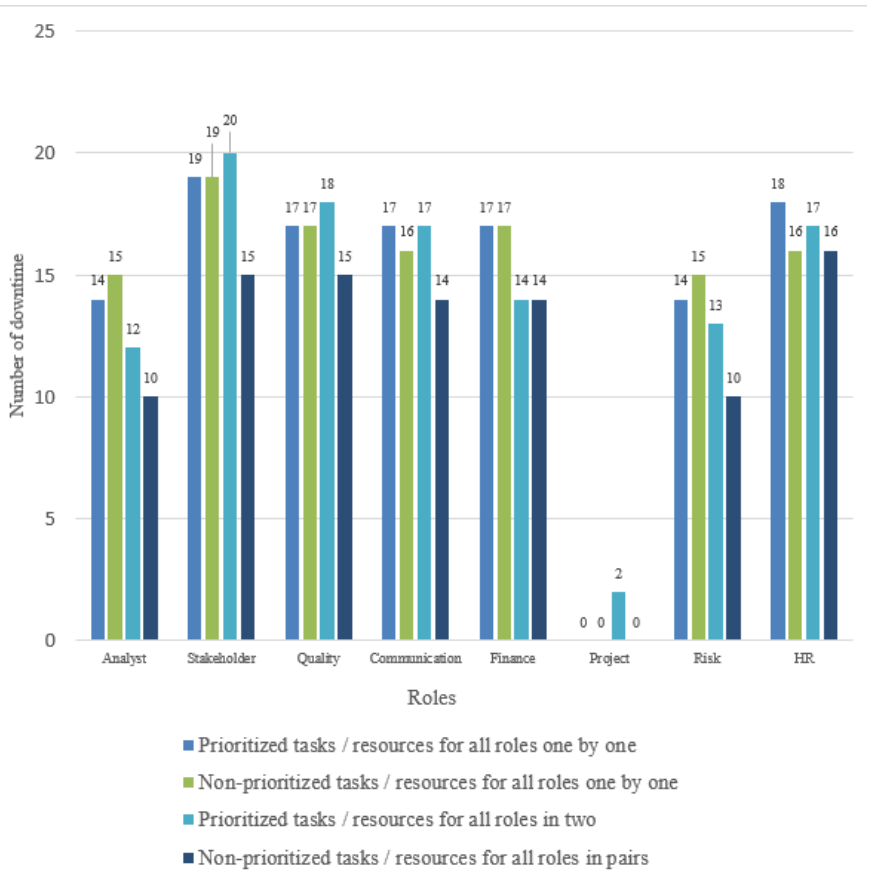

Fig. 5. Number of downtimes according to different parameters.

6. Discussion

In this paper, we aimed to answer the following research questions: 1) What uncertainties affect the dynamism of business process management? 2) What are the possibilities of CMMN to model dynamic processes? What tools support CMMN and what are their capabilities? 3) What simulation techniques would allow to simulate human work? What are the possibilities of these methods? Now, based on the obtained results, we can provide our answers.

Based on the related works, the main uncertainties affecting the dynamism of business process management are the following: the behaviour of process resources, changing conditions, and the course of tasks. The behaviour of process resources is concerns mainly with human factor, competences of resources, psychological aspects. Consequently, in the future, we can add an artificial intelligence-based process resource behaviour prediction component. Changing conditions are related to project context and application domain. As project management is extensive process, changing conditions could be impact of any specifics of each project. Therefore, additional components for description and management of a context and an application domain are necessary in project simulation. The course of tasks is one of the uncertainties that affecting the dynamism of business process management, as it can changing depends on scope of the project and the status of the project.

The CMMN has ample scope for modelling dynamic processes, as this notation illustrates the execution of dynamic tasks according to the respective stages, the relationships between the stages and the dependencies of the stages or other elements of the case.

There is currently no large selection of CMMN modelling tools on the market. The open source Flowable tool has been chosen because it currently has the most CMMN-related functionality. Agent-based simulation and its application are the most suitable for simulating the execution of dynamic processes, as it allows simulating human work and

changing conditions.

This research work had some limitations. The main one was that simulation results are based on randomly generated data. It would be more precise if data would be gathered from real projects. Real projects data could ensure suggested model verification.

7. Conclusions and future works

The developed software project management CMMN model illustrates the project management execution process. It helps to visualize and clearly understand, which parts of the project management can be started dynamically, and which can be started consistently. Because of project management dynamic tasks that are interdependent, the CMMN model shows which tasks should have a higher priority in the execution process.

The proposed CMMN model was implemented into a prototype and the experiments have been conducted. The obtained results showed that the proposed model in feasible and can be used for a SS project simulation. Moreover, the obtained results allow us to determine: 1) non-prioritized tasks with one allocated resource; 2) non-prioritized tasks with two allocated resources; 3) prioritized tasks with one commonly shared resource; and 4) prioritize tasks with two commonly shared resources.

The experimental study can be extended to include new input parameters that should be considered during the project (e.g., employee motivation, availability, and experience). Also, this study can only be used by combining the sources of the same project roles into one - if an agent is working on a specific task, freeing up another agent can help with the task that has been started and in a timely manner. The results of the simulation can be returned by a specific indicator that could be measured by examining effective efficiency, paying for the ratio of time to time of execution of the relevant task, or another indicator.

To sum up, work is still in progress and in the future we plan the following works:

1. Validation of the proposed model by comparing it with other approaches.
2. The data gathering from real projects and preparation for model verification.
3. Using fuzzy theory for extending project management model and its simulation.

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