Use of simulation in the public sector

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Abstract—Methods and techniques of business process management as known in the private sector are being used more and more in the public sector. This paper demonstrates their applicability to systems where the human factor is more important. It describes a case study of filling unoccupied capacities in an old people's home. The simulation techniques are used as a replacement for the exact deterministic planning. Our research shows that by using the simulation it is possible to predict the effects of the renovation and the duration of the processes and bottlenecks and to thereby avoid bad decisions**.**

Keywords—Public administration management, Modelling, Simulation.

I. Introduction

RESERVE management is a process that ensures that adequate official public sector foreign assets are readily available to and controlled by the authorities for meeting a defined range of objectives for a country or union [IMF 2009]. Organisations are often not aware of the 'internal reserve' they have at their every day functioning. Specially when they are not forced to keep the track of every expenditure. It usually happens when they have an absolute monopoly on the market. This is often the case in the sphere of public services.

Our case study dealt with an old people's home. It operates in an environment, where demands fully exceed available capacities. There are more than 17.000 applications on the waiting list at the moment [SSZS 2009] for about 18.500 places. Therefore there is no wonder that not enough attention was paid to the fulfilment time of the released place. The existing information system of the old people's home was not organised in the way of showing the lost time between the event of the released place and the occurrence of its new reoccupation.

Two main goals have been stated for the research. The first one was to prove that in the admission process in the old people's house there are internal reserves in the organisation. Some of them can be acquired with the new organisation of the process. The second goal was to demonstrate that the discrete simulations can be a substitute for the incomplete information system. They are some kind of extension to the existing information system. In the aim of achieving these stated goals two models of the admission process have been developed. In the first one the existing process as it was organised before the reorganisation was modelled. The second model represents the same process after the reorganisation.

II. Business Process Modelling and Simulation Modelling

Simulation can be used in the analysis of any system to ensure the quality and efficiency of stochastic, complex processes that operate in resource-constrained environments. Furthermore, most service systems are fairly well defined discrete processes [Laughery et al. 1998]. After the first simulations which were used to simulate the production process they are more often used also to analyse services. Need for the usage of simulations in the public sector suggested Rouillard [Rouillard 1999]. Now, simulations are a constituted part of modelling and analyse which are the first phase of the Business Process Management lifecycle by the Service Oriented Architecture SOA [Juric and Pant 2008]. They are a common tool for testing a new process model before the implementation [Harmon 2003], [Kritchnchai and MacCarthy 2002], [Eldabi et al. 2002], [Robertson and Perera 2002].

There are many cases of simulation usage for processes in the public sector. Greasley and Barlow [Greasley 2005] analyzed a business process approach to a change in a custody-of-prisoner process. Ozbay and Bartin [Ozbay and Bartin 2003] studied an incident management situation with the Arena simulation package. Hlupic and de Vreede [Hlupic and de Vreede 2005] used simulation modelling and analysis to reduce the risk of business process innovation in an outpatient's department. Kovacic and Pecek [Kovacic and Pecek 2007] studied the influence of the law changes on the process productivity of the social grant application.

It is common to all of these studies that the main observed value is the transaction cycle time. By Kaplan and Norton [Kaplan and Norton 1996] it is the indicator of throughput time. It helps to visualize the impacts and implications on a new process [Chen 1999].

In our research one other very important key performance indicator was exposed. We wanted to find out the number of the unused beds per year or average number of days needed to reoccupy the released place. It shows the agility of the administration finding a new patient.

As the information system was not able to give the answer about the time lost between the release place and the reoccupation we decided to gain this data from the simulation model.

Rockwell Arena software is the most popular software for the discrete simulation modelling [Anglani et al. 2002], [de Swaan Arons and Boer 2001], [Perera and Liyanage 2000], [Fowler and Rose 2004]. Micrografx iGrafx Process 2007 is a similar tool to the Arena. They both provide a simulation support environment (SSE) in which it is possible to quickly create system models interactively and manage all phases of the simulation project, including generation of the simulation code execution of the simulation [Seila 2005], [Melao and Pidd 2006]. For the research iGrafx was chosen. The deciding point represented the fact that iGrafx uses swim lane diagram for the basic process drawing instead of plain block diagram which is the case in the Arena software. There are only few articles mentioning this software with the connection to the simulation engineering [Bosilj Vuksic et al. 2002], [McCharty and Stauffer 2001], [Groznik et al. 2003], [Noakes 2005] and [Kovacic and Pecek2007].

For a drawing technique a swim lane diagram has been chosen. It is one of diagrams used in the Unified Modelling Language which is by many authors recognised as a 'de facto industrial standard for the information engineering' [Engels et al. 2000], [Siau and Halpin 2001], [Pender 2003].

III. The Existing Practice of the Procedure of Admittance

The observed home cares for about 200 patients. On average, capacities are released between 60 and 65 times a year (2006: 62; 2007: 69; 2008: 59). The procedure for accepting a new client was simple and more or less, carried out as follows: The client filled in an application. Administration accepted it and analysed space available. If there were no place available, administration prepared information on the temporary overcrowded status and sent it to the applicant. He or she was suggested to try again next time after two of three weeks. If there was a free place available then the applicant was registered and sent for a medical check-up. The medical council decided whether the applicant really needed medical nursing and was suitable for the acceptance. In such case the competent commission convened taking place the morning following the examination. On the basis of the free places and the medical council's diagnosis, the acceptance commission made a final decision on the acceptance of the applicant. According to the health care and needs, applicants were sorted into four categories: self-dependent, occasional help needed, demanding and 24-hour demanding. The applicant might be refused if the type of the free place and the client's demands were not compatible. In the case of a rejection, information on the rejection was prepared otherwise, the administration prepared a contract. The applicant or his/her relatives signed the contract. (In the majority of cases, the relatives accepted the stated conditions). The applicant referred to was accepted the following morning when his or her documents were prepared. The medical council described the needed nursing. If the conditions of the contract were not accepted the applicant withdrawn.

In the case when the applicant was refused due to the overcrowding, results of the medical counsel or by the acceptance commission, the he or she was advised to try again after two or three weeks.

The most surprising fact was the realisation that no waiting list or similar reference was kept for the rejected applications. As to the question of "why", the answer was a simple: "there is no need for it. In many cases, after a new free place would be released and offered, the applicant would not need it any more". Regarding the next item concerning the fact that there is a free place unoccupied till the next application arrives, the very convincing answer from authorities was given: applications arrive every day, so it does not represent any problem at all.

The existing bookkeeping system did not offer any tracking about the unoccupied places and therefore was not able to give any information on the vacancies available at the old people's house. We could say it was not able to furnish any figures about the lost opportunities. Any unoccupied place of at least one day represents a lost opportunity for the institution as it cannot be charged to anyone. Although it may be hard to imagine it, the reason for not tracking the lost opportunities was very simple: nobody was ever interested in this kind of data. The main goal of the existing information system was to keep track of all payments and to request debtors to pay their bills.

The model of the described procedure of admission is presented in Figure 1. In the diagram data on the process dynamics is shown. The abbreviation'd' stands for days, 'm' for minutes and's' for seconds. Data was given by the operative staff.

With the intention of making the model as realistic as possible, three additional modifications of the activities have been made. The activity "convening of the commission" was marked as only taking place at the end of the day, while "examination" and "admittance" occur in the morning. Both definitions are entered into the program on the page describing input properties of the action by marking "collect transactions on input" with the "gate by time" option.

Two transaction generators are implemented in our model. The first one simulates occurrences of released places. The frequency of transactions was calculated by the data, that there is on average, about 60 to 65 releases per year. Therefore, transactions are generated with the uniform distributed time of between 1 and 12 days. This generator is integrated in the activity "unleashing". The second one simulates appearances of applications. It was assured, that they arrive nearly every

day, at least every second day. Therefore, the uniform distributed 'interarrival' time between 0 and 2 days was the frequency of the generator implemented into the activity called "filling in an application".

The goal of the simulation is to calculate the number of the lost days. These are days when one place – one bed is unoccupied. This aim is reached with the help of attributes and several in-built functions.

The first generator which simulates the occurrences of the releases has only one task: it increases the number of free places. It is done in the numeric scenario attribute "S.place". At the same time the temporary current simulation day is recorded in the numeric scenario attribute "S.Starting_free_time". This is done by the built-in function "ElapsedTime()" which returns the temporary simulation time in seconds.

In the decision "any free place?" the procedure continues over the path "yes" if the attribute "S.place" is greater than zero, otherwise it continues over the path named "no".
After the new member is admitted in the activity Admittance, the current time from the simulation clock is recorded again. The difference of days between the Starting_free_time and the Ending_free_time is summed into the scenario attribute "S.Sum_free_time".

IV. Result of the Simulation

The simulation scenario was prepared to simulate 55 years with 5warm up years. We planned the number of repetitions of the simulation with the different seed number according to the procedure described in Karian and Dudewicz [Karian and Dudewicz 1999]. Noting that the same procedure is also described in Harrell et al. [Harl et al. 2004]:
Step 1: we decided to make 15 initial runs (n0 = 15) of the simulation for the first estimation of the number of the lost – unoccupied days. From the $\omega = t_{n_0-1}^{-1}((1+P^*)/2)/d =$ a confidence P* = ,99 and the tolerance interval ± 100 days in a 50 year period a $t_{n_0-1}^{-1}(0{,}99) = t_{14}^{-1}(0{,}99)$ = 2,624 was stated from the *Student's t*-distribution.
Step 2: 15 occurrences of the simulation for the observed model were completed. Results for each individual run are given in Table 1.
Step 3: Calculations from the sample for $\overline{X}(n_0)$ = 20360,6 and s = 952,73 were made.
Step 4: A number of occurrences (n) of simulation runs for the stated confidence of 0,99 and a tolerance (d) of ± 100 days were set: $n = \max\left\{n_0 + 1, \left\lceil \left(t_{n_0-1}^{-1}\left(\left(1+P^*\right)/2\right)\right)^2 s^2/d^2 \right\rceil\right\}$, where $\lceil . \rceil$ denotes rounding up to an integer. So

$$n = \max\left\{16, \lceil (2{,}624)^2 * (952{,}73)^2/(100)^2 \rceil\right\}$$
$$= \max\{16, \lceil 624{,}94 \rceil\} = \max\{16{,}625\}_{=625}.$$

Step 5: 625 simulation's runs each with the different initialisation of the random number was undertaken. 58 minutes were needed to complete the simulations on the computer powered by 2,4 GHz CPU.
Step 6: A calculation for the 625 simulation runs was made and $\overline{\overline{X}}$ = 20100,22 was calculated
Step 7: We can claim with a confidence of 0,99 that the average lost number of days in a 50 year time is between 20000,22 days and 20200,22 days. It means that there is on the average about 402 days lost per a single year.

Verification is the process of making sure that the simulation program actually represents the intended model [Pidd 1998], [Chung 2003], [Banks et al. 2001], [Law and Kelton 2000], [Harrell et all 2004], [Seila 2005]. Validation is the process of determining if the model is useful representation of the real system [Seila et al. 2003], [Birta and Arbez 2007], [Wainer 2009].

For the first test it was considered the number of the released places per year. It was established that this number varied between 60 and 62 persons. It confirms the expected number according to data of the last three years. On the other hand the activity "analysis of the free capacity" was executed about 19500 times per simulation – in the 50 year period time. It means that there were inquiries every day! This confirms that both generators simulate reality of the process.

The main validation the observation of the exact free bed was observed. It was a difficult task as it required manually detail tracing of the everyday changes of the occupation of resources. This supervision was taking place for a month and a half. During this time seven releases have been traced. It was expected that on average a released bed is reoccupied in about 6,7 days (402 days divided by 60 acceptances). The actual data have shown that on the average this period is longer. There were manual observations of seven cases. It has taken 9, 7, 12, 6, 9, 6 and 11 days which gives average of 8,6 days with σ = 2,19. The detail analysis of the reason has shown that there were subjective reasons that extended the process – like illness of the administrator, vacations, holidays, etc. It should be included in the model, but it would demand the detail observation of the probability that something goes wrong and thus expanding the process. Anyway, the analysis has shown that the actual data do not differ from the simulated result $(z = (\overline{x} - \mu)/(\sigma/\sqrt{n}) = (8{,}6 - 6{,}7)/(2{,}16/\sqrt{6}) = 0{,}78$. At least it was concluded that the model was not pessimistic. Right on the contra it even calculated an optimistic version when everything goes as planned. Therefore it was stated that the model satisfies the expectations and therefore the model was verified and validated.

V. THE NEW PROCESS OF THE ADMITTANCE

After the calculation of wasted time for the current process, arose the most interesting question: "what do we gain, if applications are not rejected, but put in a waiting queue list? Will it have any effect on the efficiency of the institution?" Therefore a new modified version of the acceptance process was established. It was organised on the following foundations:

- Each candidate is obligated having the prescribed medical exam of his/hers abilities on his own expenses at any doctor of the common cases. The diagnosis is added to the application.
- Each application is accepted and placed into the waiting list.

Now the process after the transaction generator goes to the administration which records the data about the patient. Afterwards the commission confirms the candidate and inserts him into the waiting queue. Commission does not have many reasons to refuse the application. It decides according to the submitted medical certificate gained from the general doctor out of the institution. Therefore we stated that only 1% of applications are rejected. After a new place is released the first one in the waiting queue is called and medically examined. The medical counsel can reject the applicant only if the medical state is different according to the diagnosis enclosed to the application. It may happen only in the case of dramatic change of health during the waiting time in the queue. Therefore the same probability was used. If the nursing needed is confirmed by the medical counsel a contract is prepared, signed by the client and he or she is admitted. The counsel prepares the documentation and prescribes the health care.

There is a very important decision called 'still needed' after the new application from the waiting list is started. Now it may happen that the selected applicant who is finally called for the admittance is not interested for the life in the institution any more. Either he or she has found a new solution or the service is not needed any more. Therefore we predicted that more than the half of the offered person will refuse the invitation (60%). It such case there needs to be a feedback signal into the waiting list that another candidate from the waiting list is lunched for the admittance.

This was performed by inviting the third generator 'change mind'. In the case that a feedback signal is need a new scenario attribute "S.changed_mind" is increased by 1. And every time when this attribute is increased, the "change mind" generator generates a new transaction into the waiting list where a new waiting applicant is picked up from the waiting queue and lunched for the acceptance.

The model of the new reorganised procedure is represented on the figure 2.

The simulation scenario for the modified process was the same to the previous one. It simulates 55 years with 5warm up years.

The same procedure as for the previous model was used [Karian and Dudewicz 1999] and [Harrell et al. 2004] was used to calculate the number of simulation repetitions:

Step 1: Again 15 initial runs of the simulation have been performed. With the same level of the confidence P* = 0,99 and the tolerance interval ± 100 days in a 50 year period a $t_{n_0-1}^{-1}(0{,}99) = t_{14}^{-1}(0{,}99) = 2{,}624$ was stated from *Student's t*-distribution.

Step 2: 15 occurrences of the simulation for the observed model were completed. Results for each individual run are given in the Table 2.

Step 3: Calculations from the sample for $\overline{X}(n_0) = 9341{,}6$ and s = 716,86 were made.

Step 4: A number of occurrences (n) of simulation runs for a tolerance (d) of ± 100 days were set:

$$n = \max\left\{16, \left\lceil (2{,}624)^2 * (716{,}86)^2 / (100)^2 \right\rceil\right\}$$

$$= \max\left\{16, \lceil 353{,}8 \rceil\right\} = \max\left\{16{,}354\right\} = 354.$$

Step 5: Additional 354 simulation runs were undertaken.

Step 6: A calculation for the 354 simulation runs was made and $\overline{\overline{X}} = 9148{,}12$ was calculated

Step 7: We can claim with a confidence of 0,99 that the average lost number of days in a 50 year time is 9148,12 ± 100 days. It means that there is on the average about 183 lost days in a single year.

The simulation shows that the new, reorganised process has shorten the time of the new reoccupation of the released bed from 402 down to 183 days. It means that the new process has reduced the time of reoccupation of the released free place for nearly 55 %. Now, there is the average waiting time for a new client nearly exactly 3 days.

For the first test it was considered the number of the accepted patients. The numbers from the both models have been compared. Both numbers are identical. They generate the same number of releases and also the number of the accepted people also differs very little. Therefore it can be assumed that both generate the same conditions.

Again manual observation and tracking of the free time was performed for 15 cases this time. In six cases the reoccupation time was 2days, in seven cases 3, one case 4 and in two cases 5 days. It gives an average of 2,93 days and deviation of 1,03.

VI. CONCLUSION

Simulations of the both models clearly show that the number of lost days when an unoccupied place or places occur seriously decrease when the new organisation of the process is organised through the creation of the waiting list. The calculation show that on average it can be expected that 219 days per year less will be lost in a new type of the process organisation.

In the year 2009 one day in the house of the old people's home was charged 40 €. It means that there was about 8700 € saved money. Perhaps someone will claim that the net saving of the reorganisation is low. Perhaps someone will even say that it was not worth developing the simulation model for such a paltry sum. But there is one and perhaps the most important reason for the research. It has been proven that there are internal reserves in the organisation which can be used instead of just waiting for rising up prices. And this is a very important message to the organisation in the environment where needs highly overload the offers.

There are also some other aims realised by the reorganisation of the procedure. Medical counsel does not need any more to record candidate's data for the medical exam. It can be done by the administration. The most gained value represents the fact that in the new model only a bit more than the accepted patients are examined by the internal old people's house staff. Candidates need to gain the medical certificate in advance from the general doctor. Therefore just a routine verification is needed to confirm that the state of the person has not drastically changed since the examination was performed. The number of the examinations has therefore significantly decreased from 7731 down to 3509 in 55 year period. (The warm up time of 5 years in included in this number). It is worth mentioning that this activity is far the most expensive at all. It needs a doctor and the nurse who are always over occupied with the everyday work.

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APPENDIX

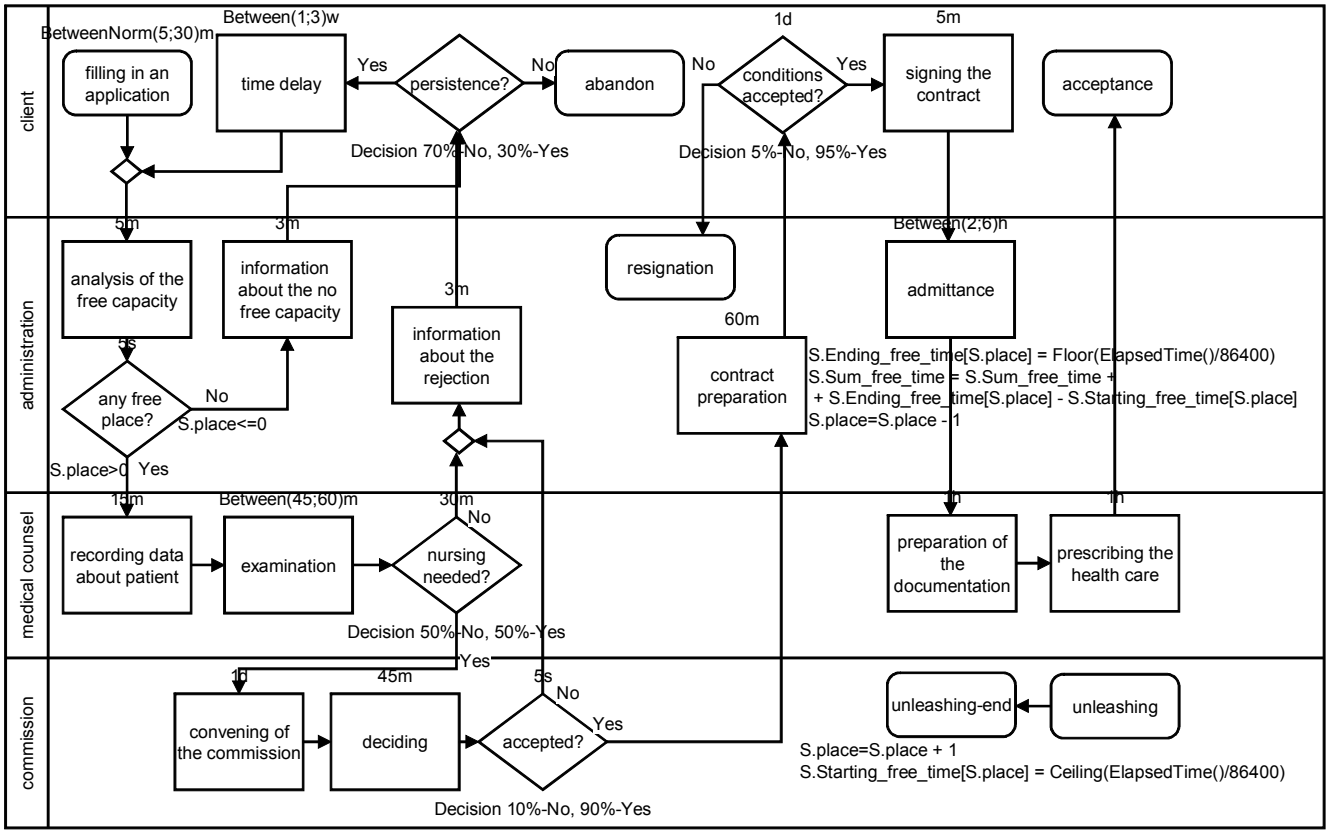

Figure 1 –Model of the Acceptance Process AS-IS

Table 1 – Results of Simulations of the AS-IS Model of the Acceptance Process

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	X	SD
Sum of free days	19379	21428	20896	18910	20849	20685	18876	20889	20778	19719	20592	21573	20411	18941	21483	20360	952,73
Accepted number	2969	3021	2982	2945	3009	3006	2951	3038	3049	3017	3036	3020	2995	2988	3019	3003	31,05
Releases in 55 years	3269	3329	3281	3240	3323	3326	3243	3337	3347	3306	3334	3325	3310	3283	3315	3304,5	33,72
Examinations in 55 years	7649	7794	7675	7580	7775	7779	7588	7809	7826	7734	7801	7779	7741	7682	7758	7731,3	78,77

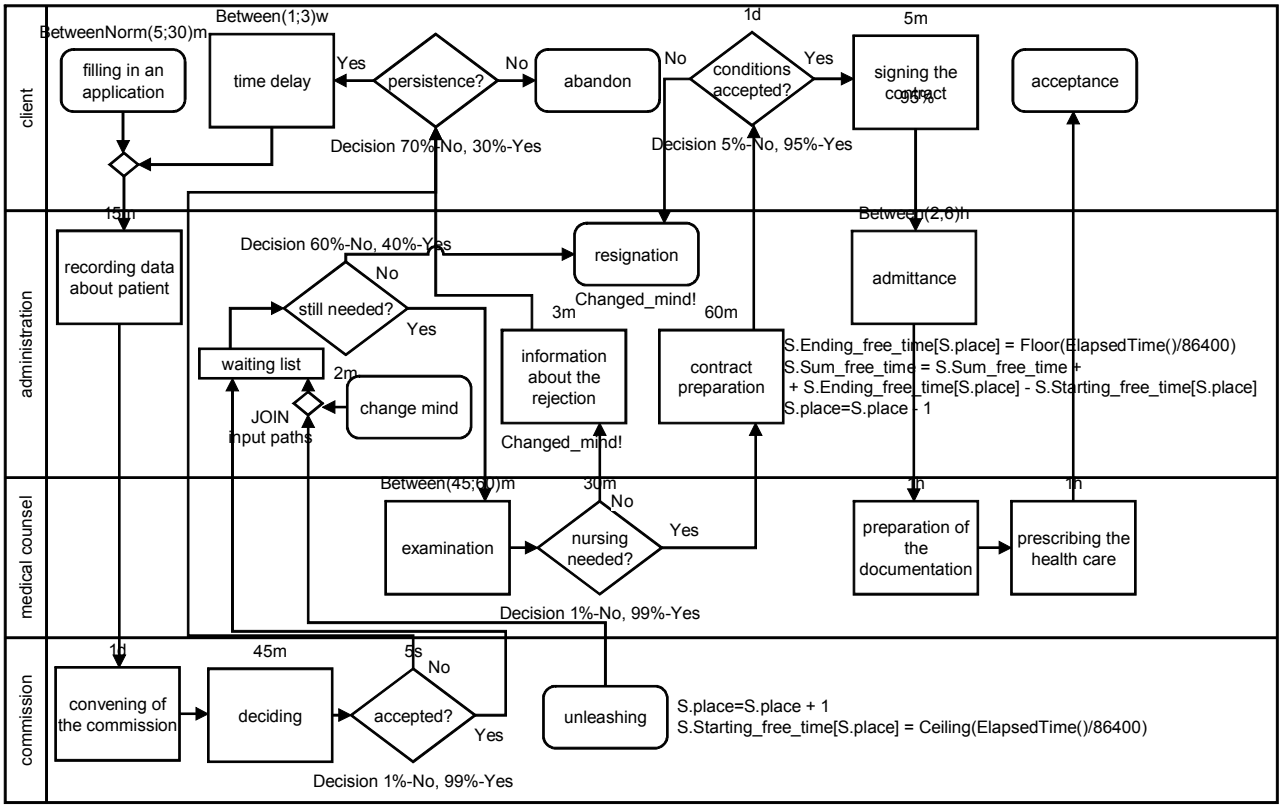

Figure 2 –Model of the New Modified Acceptance Process TO-BE

Table 2 – Results of Simulations of the Modified TOBE Model of the Acceptance Process

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	X	SD
Sum of free days	8976	9036	8945	8866	11350	10396	8759	9051	9118	9044	9117	9367	10104	8939	9056	9341,6	716,86
Accepted number	2968	3018	2981	2945	2991	2994	2948	3036	3051	3016	3035	3015	2995	2988	3018	2999,9	31,23
Releases in 55 years	3269	3329	3281	3240	3323	3326	3243	3337	3347	3306	3334	3325	3310	3283	3315	3304,5	33,72
Examinations in 55 years	3475	3534	3488	3446	3513	3521	3446	3545	3560	3516	3544	3531	3505	3491	3523	3509,2	34,34