Discrete event simulation of administrative and medical processes

Diskretna dogodkovna simulacija administrativnih in medicinskih postopkov

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Abstract

Background: Medical processes are often obstructed by administrative ones. The main issue in administrative processes is uneven workload resulting in an increased possibility of human errors. The system approach assures that medical and administrative processes are integrated. According to research reports and best practices, discrete event simulation is a proper method to implement the system approach.

Methods: A detailed analysis of the administrative processes was performed using interviews, UML diagrams and flowcharts. Based on the data gathered from the information system and measurements on the site, the distribution of patient arrivals and service times were modelled. The aim of discrete event simulation models was to replicate the behaviour of the existing system (separate administration) and to simulate the changes proposed (joint administration).

Results: Average utilizations of administrative personnel in 100 simulation runs for specific clinical departments are: 83.8 % at the Department of Rheumatology, 61.9 % at the Department of Hypertension, and 47.2 % at the Veterans' Medical Unit. Should joint administration be applied, the average utilization of administrative personnel would be 74.3 %.

Conclusions: Discrete event simulation proved that joint administration would contribute to a more even workload distribution among administrative personnel, higher quality of service and easier human resource management. The presented approach can be efficiently applied to large-scale systems e.g. organizational changes of processes in Specialist Outpatient Clinics.

Izvleček

Izhodišča: Medicinske postopke pogosto ovirajo administrativni postopki. Pri administrativnih postopkih je problematična zlasti neenakomerno porazdeljena delovna obremenitev, ki vodi do večje verjetnosti nastanka človeških napak. Sistemski pristop zagotavlja integracijo medicinskih in administrativnih postopkov. Glede na izsledke raziskav in primere najboljših praks je diskretna dogodkovna simulacija primerna metoda za uresničevanje sistemskega pristopa.

Metode: S pomočjo intervjujev, diagramov UML in diagramov poteka smo izvedli podrobno analizo administrativnih postopkov. Porazdelitev prihodov bolnikov in časov strežbe smo modelirali na osnovi podatkov, ki smo jih pridobili iz informacijskega sistema in s pomočjo meritev na deloviščih. Z diskretno dogodkovno simulacijo smo želeli ponoviti obnašanje obstoječega sistema (ločena administracija) in simulirati predlagane spremembe (združena administracija).

Rezultati: Povprečna zasedenost administrativnega osebja v 100 simulacijskih tekih za posamezne klinične oddelke je 83,8 % na oddelku za revmatologijo, 61,9 % na oddelku za hipertenzijo in 47,2 % na centru za vojne veterane. V primeru uporabe združene administracije bi povprečna zasedenost administrativnega osebja znašala 74,3 %.

Zaključki: Diskretna dogodkovna simulacija je pokazala, da bi združena administracija prispevala k enakomernejši porazdelitvi obremenitev med administrativnim osebjem in k višji kakovosti storitev ter omogočila enostavnejše upravljanje s človeškimi viri. Predstavljeni pristop lahko učinkovito uporabimo tudi na večjih sistemih, na primer pri organizacijskih spremembah na Polikliniki.

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1. Introduction

Health care organizations are faced with increasing pressures to deliver quality care while reducing costs, lowering reimbursements and introducing new regulatory requirements. One of the most widespread methods for improved decision making support is discrete-event simulation (DES). Several resources[1] state that DES is an effective decision-making tool for the optimal allocation of scarce health care resources to improve patient flow, while reducing health care delivery costs and increasing patient satisfaction. A survey of published papers[2] reveals significantly increased interest in DES in health care since 2004. Simulation models are focused on two areas:

- Allocation of resources[3,4] and
- Optimization and analysis of patient flow.[5-10]

The main topics of the published simulation models include staff optimization and reorganization with focus on physicians and nurses or operating teams. The quality of service for the patient also includes administrative processes, which are often neglected. Long reception queues at hospitals and outpatients departments, wasted effort on searching lost paper documents and delayed delivery of medical and financial documentation are decreasing overall level of service quality. Time needed to deliver the written diagnosis to the patient and doctor is another practical viewpoint showing the importance of the administrative processes in health care. It is not uncommon in Slovenian health care organizations to send the written diagnosis by mail with significant delay after the examination in an outpatient department or discharge from a hospital ward. Examination reports provide important information for further treatment after examination or discharge from hospital. Even though these documents are not of vital importance to the patients of an emergency department, the patients should get treatment as soon as possible.

Organizational process patterns shall help to coordinate interoperating healthcare professionals and organizational units (e.g. handling of a medical order and results reporting).[11] Several other papers confirm that simulation and modelling can be and have to be applied more regularly in healthcare.[12,13,14]

The project of optimization of healthcare administration business process[15] was performed at the University Medical Centre of Ljubljana, which is one of the largest hospitals in the region. In the year 2008 they processed approximately 100.000 hospitalizations and 700.000 outpatient examinations. The project defined optimization as:

1. Rationalization of administrative processes (shorter flow time, less errors, even distribution of workload among employees);
2. Standardization of activities that constitute processes in healthcare institution;
3. Informatization of the parts of the process with the goal of minimizing the effort for documentation management, increasing data security and contributing to patient confidentiality.

In mathematical terms optimization is minimizing or maximizing the goal function, while in practice the term optimization is equal to the definition adopted in the project.

2. Methods, tools and techniques used in the project

The optimization was performed in two phases. Process analysis was carried out in the first phase while a detailed simulation model was developed in the second phase of the project. Hospital management can make a decision about the location of administrative staff based on the results of the simulation model.

In the first phase of the project a detailed analysis of 15 significant administrative processes was performed. The following tools and techniques were used: structured interviews, structured texts, use case and sequence diagrams, flowcharts and preliminary simulation models. Use case and sequence diagrams are artefacts of Unified Modelling Language (UML) mostly used in software engineering for system analysis and design.[16] According to the findings, preliminary performance indicators for the

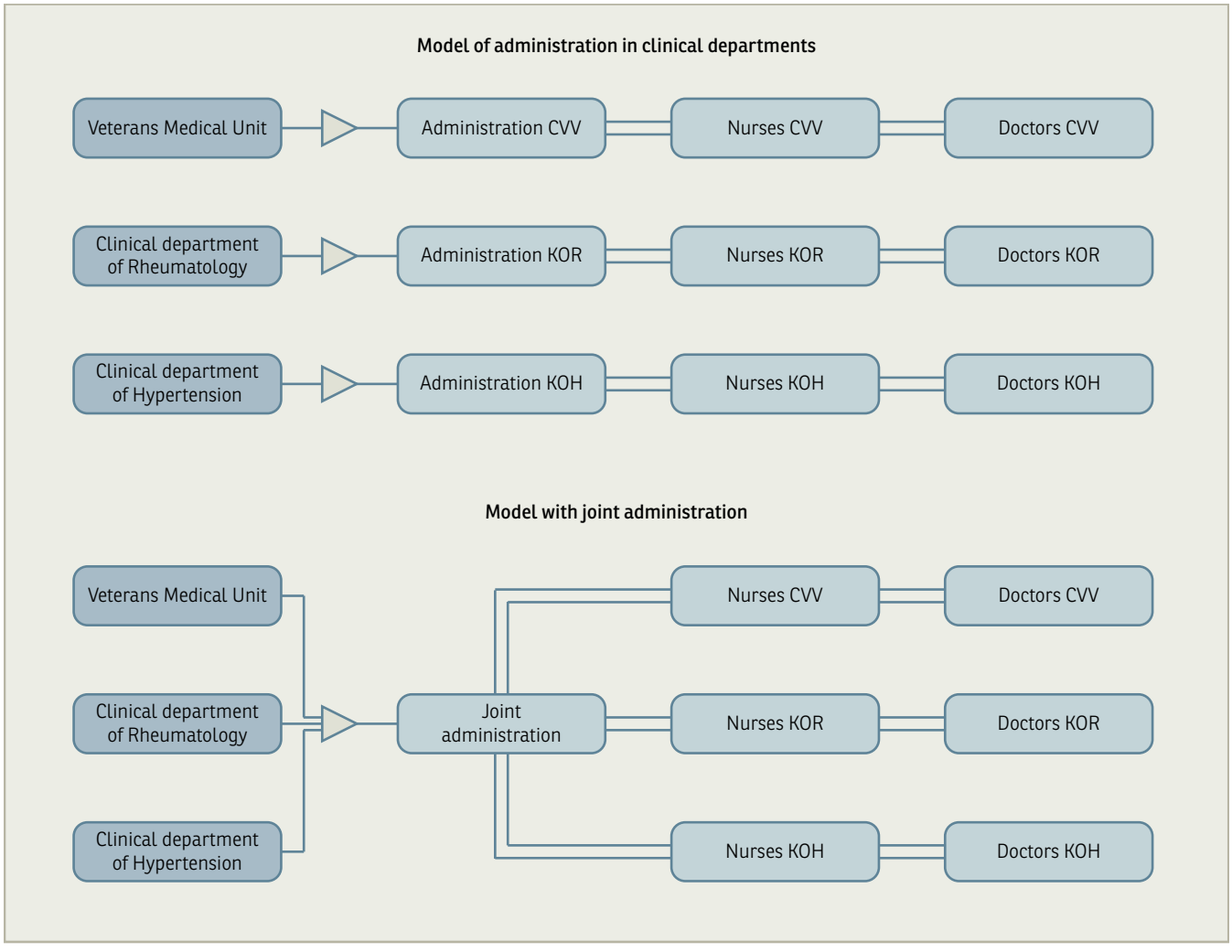

Figure 1: Existing and proposed queuing system of administrative and medical processes.

processes were set. Based on the analysis, standard administrative processes for the entire institution with approximately 500 administrators were proposed. Significantly less time would be spent on typing with the introduction of an integrated information system, and significantly less effort would be needed to manage and control these processes. A preliminary estimation revealed that approximately 274.000 working hours of administrators per year could be spared. If these wasted hours could be reallocated, patient would receive much higher quality of service. The centralization of administrative personnel management was proposed. The main benefits of the proposal are:

1. Higher quality of service for the patients,
2. Improved working environment for employees and
3. Decreased possibility of errors, mistakes and lost documents.

The second phase of the project was performed on the case of two clinics (Department of Internal Medicine and Department of Gynaecology) with several clinical departments. Based on the findings of the first phase, it was clear that a decision about joint location for administrative employees was needed. The criteria of the decision tree were elicited with brainstorming, and Analytical Hierarchy of Processes method (AHP) was used to determine the importance of each criteria.

The Department of Gynaecology was not feasible for the study of joint administrative site, while the dislocated hospital (Bolnišnica dr. Petra Držaja) which is part of the Department of Internal Medicine was. However the project team members in this site were in doubt about the expected benefits of such change. To increase their confidence in the proposed change, process models of separate and joint administrative

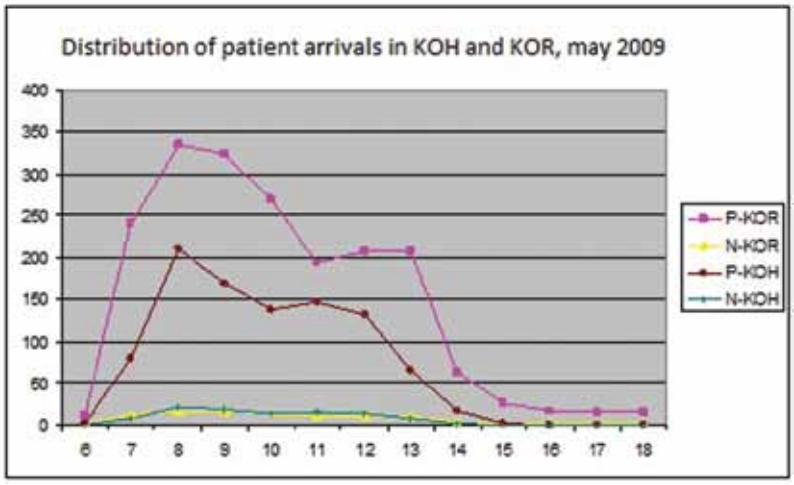

Figure 2: Distribution of patient arrivals in KOR and KOH clinical departments.

sites were developed. The most appropriate method to address the problem was DES due to its ability to accurately repeat the past processes and model the proposed changes without the need of real world implementation. The iterative development method provided gradual implementation of user requirements. GPSS (General Purpose Simulation System) was used to code the concept of simulation experiment. GPSS[17] as a simulation programming language is well known, reliable, functional and usable in terms of software quality criteria.

3. The simulation model for a dislocated hospital (department of internal medicine)

Two simulation models of administrative and medical processes (Figure1) in KOR, KOH and CVV were developed according to the findings of the project's first phase:

1. Three separated administration sites and
2. A central administration site.

Discrete-event models evolved in four iterations:

- Preliminary model: verified in the first phase of the project.
- Iteration 0: a simulation model for the administration in two outpatient departments was built (Clinical department of Hypertension = KOH, Clinical department of Rheumatology = KOR).
- Iteration 1: a simulation model was improved by inclusion of the third outpatient department (Veterans Medical Unit = CVV). The model builders knew that CVV is insignificant for the behaviour of the system due to small number of patients. However, team members on the site insisted to include CVV in the model.
- Iteration 2: team members (doctors) on the site realized that medical activities (especially outpatient survey and functional diagnostics such as EKG) must be included in the simulation model, since the administrative process is interrupted by medical activities. Special attention was paid to refining data (distribution of service times, measurement of average service times and deviations).

Data on patient arrivals were obtained from the information system. An average of 52 patients/day arrived to KOR, 102 patients/day to KOH and 5 patients/day to CVV in May 2009. The distributions of patient arrivals for first examination and control examinations between 6:00 AM and 19:00 PM are shown in Figure 2. Letter P in the graph legend indicates first examination and letter N indicates control examinations in two clinical departments. The Department of CVV is not presented on the graph due to the low frequency of arrivals. Patient service time for functional diagnostics (FD) is modelled as uniformed distributions according to the estimations in interviews by project team members.

Patients and phone call distributions of arrivals were included in the programming code. Same distributions were used for both simulation models (separate and joint administration). The distributions in simulation models were modified only for time with no arrivals (at the beginning and the end of the workday). In these cases one patient per hour was defined instead of zero arrivals, because zero division generates error at execution time. These corrections of the real empirical distribution do not significantly impact the results.

Medical activities were built in the simulation model as requested by the team members. Rough flowchart as presented in Figure 3 was used for all three departments. Reception, diagnosis typing with additional

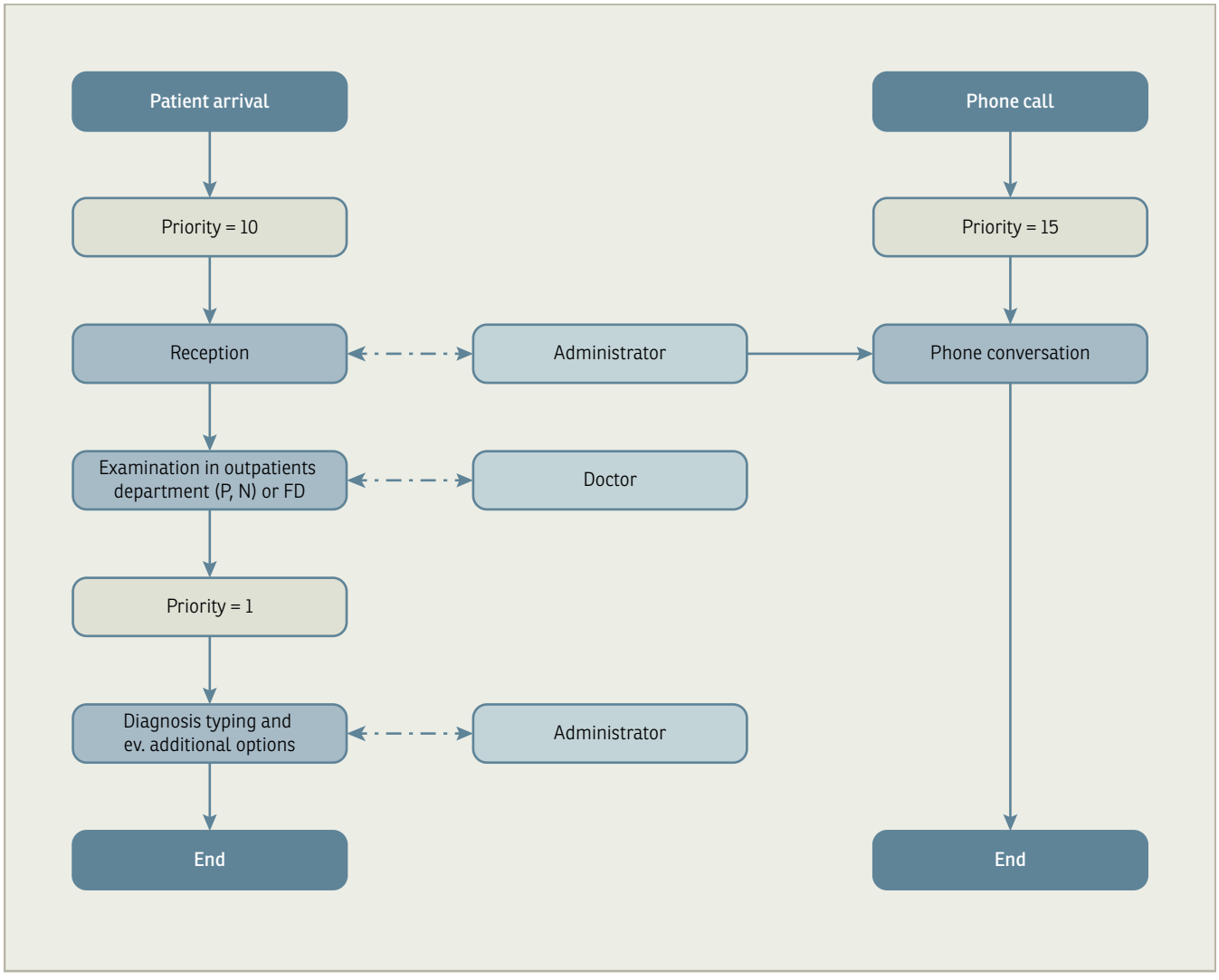

Figure 3: Flowchart of the simulation model of administrative and medical processes.

opinions and phone call answering were included in simulation of administration's workload. Examinations and functional diagnostics are considered among medical activities. Phone calls have the highest priority, while diagnosis typing with additional opinions has the lowest priority.

The shares of time used by specific administrative activities in three departments are presented in Figure 4. Only main activities were considered when building the simulation model. The simulation model includes 88.2 % of administrative time share in KOH, 86.6 % of time share in KOR and 50.3 % of time share in CVV. However the order of magnitude of the frequencies in CVV compared to KOH and KOR is 1:10 and 1:20 respectively.

The first simulation model is defined with three separate reception sites. Patient arrivals are defined as functions for each department. After the definition of variables and constants, patient arrival generators and phone call generators are defined. The average utilization of administrators is stored for each department before the end of transaction in GPSS. The GPSS code defines the number of storages (administrators, functional diagnostic units and outpatient rooms), patient arrival function, phone calls generator, flow of transaction for phone calls, patient reception, document typing etc. Simulation program itself is implemented in approximately 300 lines of code. The second simulation model uses a joint administration site, employing all 10 administrators in clinical departments. The GPSS code in the case of joint administration is presented in Figure 5.

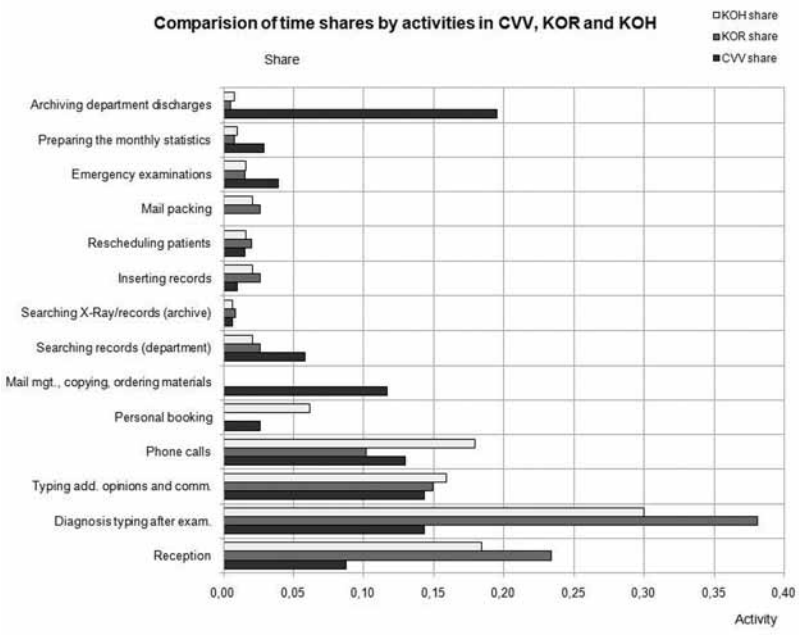

Figure 4: The structure of time used by individual activities in three clinical departments.

4. Results

The following sections summarize the results of simulation in the dislocated hospital (Department of Internal Medicine) and multiple criteria analysis of joint administrative site (Department of Gynaecology).

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                 DEPART SKUAQ
                 ADVANCE TMSpreR,TSSpreR
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RTipIzv          QUEUE SKUAQ
                 ENTER ASKU
                 DEPART SKUAQ
                 ADVANCE TMTipIR,TSTipIR
                 TRANSFER 0.6,RTipDod,Rkonec
RTipDod          ADVANCE TMTipDR,TSTipDR
                 LEAVE ASKU
                 TERMINATE
RKonec           LEAVE ASKU
                 TERMINATE
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Figure 5: The GPSS code for the simulation model with a joint administration site.

4.1 Dislocated hospital (Department of Internal Medicine)

The time scope of one simulation run was 13 hours, from 6:00 AM to 19:00 PM. Examples of administrator utilization in a simulation run are shown in Figure 6 and Figure 7.

After running over 100 simulation runs average scores were computed. Some further corrections were necessary for proper interpretation of simulation results:

1. The simulation model did not include all activities of the administrative employees. Non-implemented activities were considered in refining scores for specific server (administrator).
2. In the simulation model, the working shift lasted 13 hours. Correction factor was used for all three departments, since legislation permits only 8-hour working day with very stiff restrictions for overtime. In rush hours students are employed on a part-time basis.
3. Statistical data of workers' absence (illness, vacation, professional development) were used to refine scores in all three departments.

The final results of administration utilization are shown in Table 1.

Simulated results of separate model are in line with a subjective impression based on observation of the real system. A joint model would immediately relive the highest occupancy in KOR clinical department.

4.2 Department of Gynaecology

A feasibility study of joint administrative sites at the Department of Gynaecology was performed. Main findings were as follows:

1. Administrative sites are located in separated, geographically distant buildings with bad logistic connections. Maximum distance between two administrative sites is more than 500 meters. From the logistical viewpoint, setting the central administration site in one of the existing buildings is questionable due to road crossing, architectural barriers and risk of patient accidents on the way. There was no plan to set the hospital wards,

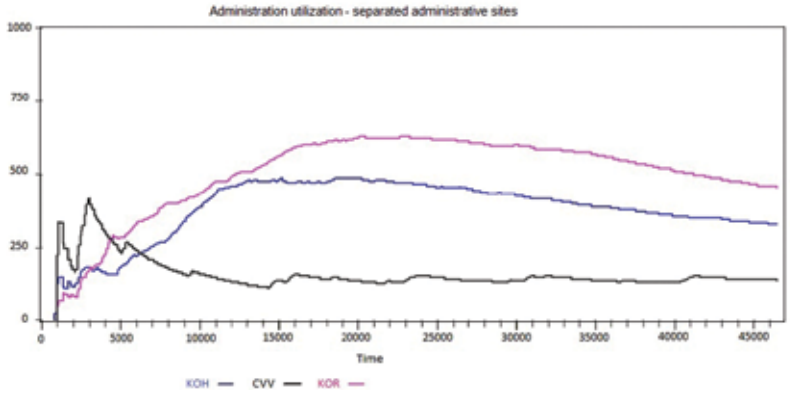

Figure 6: Example of administration utilization in a simulation run with separate administration sites.

outpatient departments and functional diagnostics within one building.

2. According to multicriteria analysis (AHP method) of administrative site reallocation, the decision maker should consider the following sets of criteria with corresponding weights: patient and staff satisfaction (0.50), security (0.41) and costs (0.09). A joint administrative site would decrease patient satisfaction and safety and require substantial investment. Based on these facts, the decision group proposed to improve the existing layouts of two administrative sites. The estimated effects of layout improvements are increased confidentiality for the patients and low investments. Discrete simulation of administrative site before and after the change is economically not justified.

5. Discussion

two clinics were involved in the project. It was established that central administrative location for the Department of Gynaecology was unfeasible. Due to geographic distribution of clinical departments the quality of service for the patients would significantly decrease with single reception site. Therefore, project efforts were focused on the improvement of working environment and assuring confidentiality for the patients. We proposed the change of the reception layouts, which would require minor investment.

At the Department of Internal Medicine central administrative location was feasible. The results of the simulation models for the observed departments showed that performance indicators (queues, lead time) of separated administration sites were lower than performance indicators of joint model. The average waiting time is especially long at KOH. An additional administrative workplace for this department is economically unjustified. Separated reception sites are also more demanding from the management viewpoint and more burdening for the employees in case of sick leave, vacations or education. In the case when only two administrators are present in the KOR department, the process cannot be performed without replacements. Waiting time is acceptable in the case of three administrators working in a joint reception site. With only two administrators present at the joint reception site the process can still be performed, even though waiting times are unacceptable from the patient's viewpoint. A joint administration site enables easier coordination of the workload in case of employee's absence; process management is easier and cheaper. The level of service is higher (with no extra costs) in the case of a joint reception site compared to separated administration sites.

Until the end of our research neither quantitative data on the utilization of administrative personnel nor the effects of occupancy were published. Industry uses a general rule of thumb that occupancy up to four-fifths for manual workers is acceptable. We presume that personnel occupancy correlates with hospital overcrowding. Research[18] concludes that hospital and emergency department overcrowding is associated with an increased mortality. Another patient-safety issue is related to transcription errors. A recent study in teaching hospital[19] clearly showed that errors at

Figure 7: Example of administration utilization in a simulation run with a joint administration site.

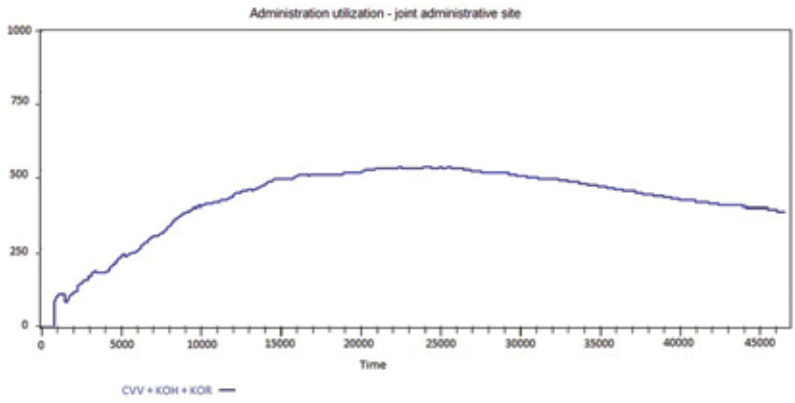

Table 1: Final results of the simulation models with separate and joint implementation of activities.

Clinical Department	KOR	KOH	CVV	Joint
% of utilization	83.76	61.92	47.15	74.30

transcription stage were not infrequent. The most common transcription error (52 %) was omission and the patient did not receive the medication that was ordered. The study proposes implementation of surveillance systems to reduce these errors. In our case we suggest voice recognition software to avoid transcription errors and to decrease occupancy of administrative personnel.

However, significant overall improvements including patient safety and quality of service can provide a tightly integrated information system (effects: no retyping, no lost documents) and voice recognition system (effects: decreased workload of administration personnel, less errors in transcriptions). These measures require substantial investments.

6. Conclusions

Even though there is a lot of research on simulations in healthcare institutions, there is a lack of optimization in complex processes. Based on a process analysis, simulation models for three clinical departments were developed. The first simulation model includes separate administration sites for each clinical department, while the second simulation model joined the administrative staff in a single administration site. In terms of costs and workload, the second model, including a joint reception site for all three clinical departments, is more appropriate. The process can still be performed even though only two administrators are present at work. A joint administration site also ensures easier coordination and management of the process while providing better quality of service for the patient.

Only main activities of the processes were included in the simulation models. To properly interpret the results of simulation models we used correction factors. Simulated utilization scores of administrative personnel in CVV, KOH and KOR were 14.02 %, 31.86 %, and 43.86 %, respectively. The estimated real utilizations were 47.15 %, 61.92 % and 83.76 % respectively for the separate model and 74.30 % for the joint model. It is also our subjective evaluation (based on observation and numerous interviews) that administrative personnel when fully utilized is possibly causing human errors: a) in transcriptions (such as omissions when prescribed medication does not reach the patient, requests for more drugs, wrong doses and unauthorised changes) and b) lost paper documentation. The simulation showed that a joint model would slightly disburden the most utilized personnel at virtually zero costs.

The presented Simulation models can provide decision-makers with essential answers before any change is actually implemented. The presented simulation approach can also be efficiently applied to large-scale systems, e.g. organizational changes of processes in the Specialist Outpatient Clinics.

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