Simulation and Multiple Linear Regression to model patient flow at an outpatient clinic

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Abstract:

This paper treats the problem of patient flow in an outpatient orthopedic clinic. A detailed description of the service and the main pathways followed by patients during their care process are provided. In fact, modeling patient flow served to improve healthcare delivery in the clinic by identifying the sources of delay. In this context a list of improvement scenarios are proposed and evaluated using Discrete Event Simulation (DES) model. The proposed changes have resulted in a great improvement in terms of minimizing the patient waiting time. A Multiple Linear Regression Model (MLR) is then proposed in order to clearly visualize the individual effect of each scenario on the average patients lenght of stay. in order to enables managers to compare these scenarios and adopt the suitable strategies for each type of paths.

Keywords**:** Patient flow, Waiting time, Discrete event simulation, Multiple linear regression.

1. Methodology

1.1 Discrete Event Simulation modeling

Modeling the patient's flow into the outpatient orthopedic clinic using the DES is used to detect the sources of dysfunction in the process and the causes of the long waiting time. In fact, the main advantage of simulation over other modeling techniques is its ability to perform the "what-if" scenarios by changing the model rules and assumptions. The DES model is used to better understand the actual process and detect the sources of dysfunction. In addition, the DES model help us to implement the proposed scenarios and then evaluate the system performance to determine if the implemented change resulted in real improvement

In addition to the best reproduction of the studied system, the advantage of the discrete event simulation is its capability of integrating probability distributions and statistical parameters that describes the real system behaviors. This capability enables us to integrate the different statistical distributions of the system parameters. After building the DES model, we proceeded with the validation step which consists in proving that this model effectively reflects the observed real system. For this reason, the model was run for 100 replications of 24 hours and then the generated results are compared to the real collected data. A comparison was conducted between the observed LOS (real) and simulated one at each stage of the care process. This included computing 95% confidence intervals for patient LOS at each stage for both simulation output and historical data. The differences between the observed and the simulated LOS are less than 4 minutes. These results confirm the validity of the simulation model. Therefore, the proposed model is useful to generate the proposed scenarios and test and evaluate them according to the key performance measures (LOS).

In fact, the collected data show a great disparity in the elapsed time to go through the different stages of the care process. The simulation model confirms our expectations about the source of the long LOS. The model indicates that patients spent the majority of time at registration payment and consultation (medical surgical). In addition the model identify that the late arrival of surgeon is another problem that causes significant delays for patients.

In this work, we detect a list of area in which we could potentially produce a significant improvement without disrupting the outpatient clinic practice. Actually, since that the sources of dysfunction are fixed and after discussions with the administration, three scenarios can be proposed: 1) increase the number of registration (or payment) agents. 2) Increase the number of assistants. Or 3) increase the number of residents.

1.2 Linear regression:

The linear model is a forecasting technique that helps making a simple modeling of the relationship between dependent variable and one or more explanatory variables. Therefore in our case, managers could predict the deviation of the waiting time if one of the proposed changes (scenarios) is chosen which enables them to adopt the suitable strategies for each of the two paths (short and long) followed by patients inside the outpatient clinic.

Modeling the average patient's *LOS* into a linear model aims to highlight the potential effect of each of the three proposed scenarios.

The average length of stay LOS_k of patients following path k can be written as follow:

$$LOS_k = \beta_0 + \beta_i X_i + \varepsilon_i$$

Where:

- X_i represents the scenario of index i, i=1, 2 or 3.
- k=1or 2, with 1 represents the short path and 2 represents the longest one.
- ε_i is a correction.

Data analysis was made using XLSTAT tool of Microsoft Excel. Before applying this analysis we should prepare our database. For this reason, we simulate each of the three proposed scenarios with 100 replications for each type of path (short and long). As a result, we obtained 600 values of average LOS (3 scenarios * 2 paths * 100 replications). In additions, we had 200 values of average observed LOS of the real system (with the short and long path).

In order to study the potential effect of the three proposed scenarios on the average LOS, two regression models are separately made for each type of path.

As result, the explanatory variables explain 71% and 69% (R^2) of the LOS variability of respectively the short and the long patient paths. Thus we can use these models to predict the effect of the increasing number of the registration agents, the assistants and the residents on the average LOS generated by each path. Therefore, managers will be able to compare the three proposed scenarios and adopt the suitable strategies in order to improve the outpatient's clinic performance.

2. Results and discussion

After the analysis, the parameters of the models are determined and therefore the effect of each scenario on the average LOS is now known.

Statistical analysis of data taken before and after the implementation indicates that the average waiting time is significantly improved and the average LOS in the outpatient clinic is reduced

2.1 Short patients path

For the short patient path, the linear model is given as follow:

$$TUBS_1 = 77.72 - 20.22\, X_1 - 22.65\, X_2 - 19.78\, X_3$$

As indicated in this model, the average LOS in the short path is 77.72 minutes. This value can be reduced respectively by 20.22, 22.5 or 19.78 minutes when respectively scenario1, scenario2 or scenario3 are adopted. Therefore, adding one new registration (or payment) agent improve the average LOS by 20.22 minutes, while adding respectively a new assistant or a new resident can reduce the average LOS by respectively 22.5 and 19.78 minutes.

The standardized coefficients show the effect of the three scenarios on the average LOS of the short path. In fact, scenario 2, which consists in adding new assistant, shows the best result which has a greater effect on the average LOS, compared to the two other scenarios

2.2 Long patients path

For the long patient path, the linear model is given as follow:

$$LOS_2 = 84.43 - 16.92\,X_1 - 17.10\,X_2 - 22.48\,X_3$$

The estimated average LOS in the long patient's path is 84.43 minutes. According to the linear regression model, this value can be respectively reduced by 16.92, 17.10 or 22.74 minutes if respectively scenario1, scenario2 or scenario3 are adopted. For example, one additional resident can reduce the average LOS by 22.48 minutes, which represents the best possible improvement of the average LOS. This strong effect of adding a new resident (as an independent variable) on our dependant variable is also justified by its standardized coefficient which is equal to 0.957.

3. Conclusion and future research

Our objective is to detect the sources of delay in patient flow and propose the best configuration of resources that minimizes the average LOS related to each type of patient path. At first time, we proposed a DES model that reproduces the system behavior with a good degree of reliability. This model is used to test the potential effect of a list of proposed scenarios on the average LOS. In order to help managers adopt suitable improvement strategy, a linear regression model is proposed. This model is used to compare the proposed scenarios and determine the weight of each one of them based on the estimated deviation of LOS related to each type of path. Therefore, the major contribution of our work is to separately treat each type of patient's path and propose a suitable improvement scenario. In fact, Given that both paths are strongly related and many resources are shared, we plan to extend this work by using methods of compromise that take into account the different pathways in a single solution.