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ISSN: 2637-4900

Journal of Community Medicine

Open Access | Research Article

A Statistical Study on Outpatients: With Special Reference to NIIMS Hospital

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Abstract

In this paper, a stochastic model for outpatients (OPD) has been developed, based on patient arrival of the NIIMS hospital in Gautam Buddh Nagar, India. Data has been collected from OPD arrival per day in the hospital. A pattern of arrival of OPD patients has been analyzed using ANOVA and some other statistical tools. Arrival rates are periodic over a week and day of week are studied and discussed graphically also. There is significant effect among the day of week on arrival of patients.

Received: Jun 11, 2020
Accepted: Jul 28, 2021
Published Online: Jul 30, 2021
Journal: Journal of Community Medicine
Publisher: MedDocs Publishers LLC
Online edition: http://meddocsonline.org/

Introduction

As we know that hospitals are the key centers for providing health care services where every health seeker can get facilities, facilities of hospital are of varied types. Most of patients visit to the hospital as outpatients for diagnosis, therapy, or treatments and leave without a stay while others are admitted for short period or long period of time. In this situation, statistical analysis is very important to know the pattern of arrival of patients in any hospital. Aim of such study is to improve the efficiency and quality of health care system. Similar studies have been carried out by different researchers, such as Ward and Xhang [1], Manning [2], Faddy [3] Hastie and Tibshirani [4] and among others.

A study was conducted in South Africa by Hastie et al [5] where X-rays of 273 women from the Mseleni area (X-rayed in earlier surveys) were reviewed, and the opportunity was used to screen pelvic X-rays for the presence or absence of osteoporosis, a demineralizing bone disease. They applied smoothing as a non-parametric alternative to ordinary linear regression, and thereby deduce the correct form for subsequent parametric regressions.

A similar study was carried out in Norway to know the pattern of patient flow in hospital for optimizing resources, differ-

Cite this article: Shukla KK, Singh R. A Statistical Study on Outpatients: with Special Reference to NIIMS Hospital. J Community Med. 2021; 4(1): 1034.

ent factors were taken into account in his research such as priority of patient, quantity of physicians and nurses, beds in the ward etc. for detailed about this study, it can be seen in Lei Zhao and Bernt Lie [6].

The available outpatient flow data is influential which includes arrival and departure times of individuals' patients, but there is a limitation also in that it does not cover about patient's stay in the hospital. In this way, on the basis of given outpatient data one can able to proposed roughly about appropriate stochastic model which includes different variables related to outpatients.

In this paper, we focus on analyzing the outpatient flow data to determine about good aggregate stochastic model of the outpatient department. Stochastic model can help to improve health care design and operations which is beneficial for both, patients as well as service provider in the hospital.

This study has been divided into four sections. Introduction about pattern of arrival and related review works are mentioned in first section. In the second section, brief description about NIIMS hospital and Data has been reported. Model of arrival and its analysis part has been discussed in third section. Conclusions have been drawn in the last section.

NIIMS hospital and Data

For the completion of this research, data has been collected between October, 4, 2019 and February, 29, 2020 from arrival patients in Noida International Institute of Medical Science (NIIMS) hospital, which is located near Delhi (capital of India) of Guatam Buddh Nagar district in India. Numbers of hospitals are located near National Capital Region (NCR) Delhi area. Many of them are providing very good services at international levels. NIIMS hospital is recently established and providing services to rural and suburban people who are living the periphery of the Dankaur (Block of Guatam Buddh Nagar) suburban area. Total of 127806 samples are collected between above given period of time. Detailed about the sample size (number of arrivals) are categorized in the table 1.

Table 1: Number of arrivals in different departments.

Sr. No	Data Description	Sample Size	Mean(/day arrival)	SD	Q_1	Median	Q_3
1	Total OPD	127806 (210 days)	608.6	290.11	589.5	678	766.0
2	Emergency (EM)	7248 (210 days)	34.51	18.95	22	32	41
3	General Medicine	24028(175 days)	137.30	35.94	120	133	153.5
4	TB_Chest	5311 (175 days)	31.24	10.40	26	29	37
5	Dermatology	8852 (175 days)	50.87	17.91	40	48	59.75
6	Psychiatry	4479 (175 days)	26.34	11.20	19	22	34.75
7	pediatrics	10922 (175 days)	62.41	18.42	56	63	70.50
8	General Surgery	18290 (175 days)	105.11	26.27	93.25	107.5	120
9	Orthopedics	13230(175 days)	76.03	17.61	69.0	77.0	85.0
10	Ophthalmology	10539 (175 days)	60.57	22.42	46.0	57.0	73.0
11	ENT	8647 (175 days)	49.98	15.48	41.0	47.0	58.0
12	Obste_Gynae	12295 (175 days)	70.26	18.92	62.0	70.0	78.0
13	Dentistry	3965 (175 days)	22.92	11.38	14	23.0	32.0

Table 1. indicates the total number arrival of patients and its distribution in differrent department on each day from October 4, 2019 to February 29,2020 (30 weeks). Total of 127806 samples are collected between 30 weeks (study period). The 30*7=210 daily total arrival and have mean 608.6 and median 678. We have also computed standard deviation of total as well as department wise arrival, and observed that moderate level of over dispersion for the daily totals compared to a Poisson process. Department wise arrival of patients were recorded only on Outpatient Day (OPD), where all Sundays of week between above mentioned study period and some particular holidays are subtracted from total 210 days, i.e. 175 days.

The outpatient arrival process and its analysis

In this section, total arrival of outpatients has been studied. This section is divided into two sections. In section 3.1, we discuss at the daily totals; we briefly discuss dependence among the daily totals of patients and presented it graphically. Dependence of patients is discussed using model in section 3.2.

Daily arrivals (outpatients)

Total number of arrival and Average number of arrival according to the day of week are presented in figure 1 &2 respectively.

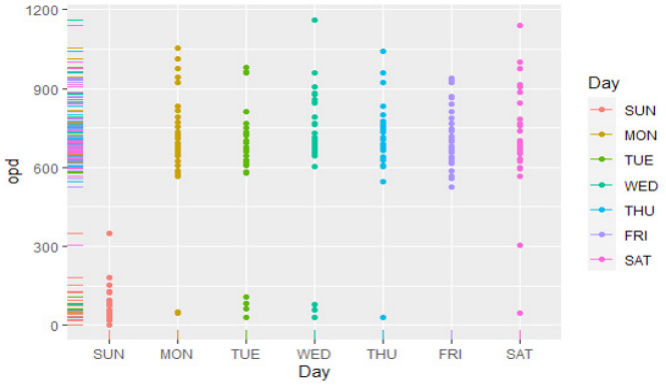

Figure 1: Day wise arrival total over day of week.

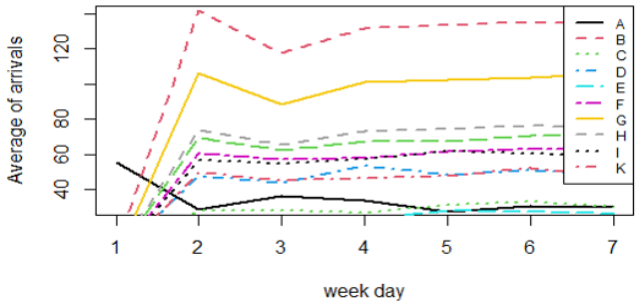

Figure 2: Average number of arrival over week day in different departments.

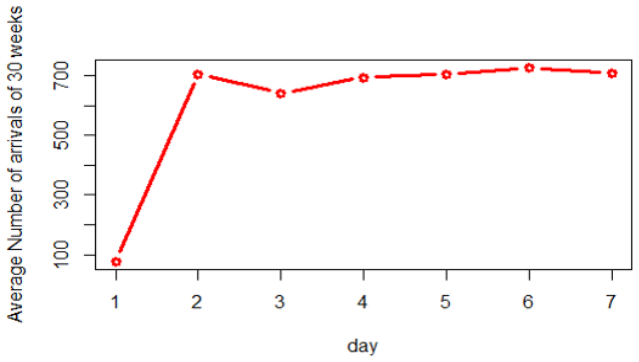

Figure 3: Average number of arrival over day-wise.

Average distributions of total arrival in different department according to week of day are presented in figure 2 and day of week is indicated on the x-axis whereas average number of arrival is indicated on y-axis and Number of department such as Emergency, General Medicine TB Chest, Dermatology, Psychiatry, General Surgery, Orthopedics, Ophthalmology and ENT are represented as A, B, C, D, E, F, G, H, I and K respectively.

From the figures 2&3, it is observed that average arrival of patients were found very low on Sunday which is indicated as day-1 of the week it is due to closing day of the hospital and only Emergency department is open on that day. Numbers of arrival were found highest on Monday which is due to holiday of the hospital on Sunday, which is to be expected because it is the beginning of the work week in India. Tuesday is the least reporting day of outpatient in the week; it may be due to reason of particular day (Tuesday day). In India, Tuesday is considered as holy day (especially in Hindu religion) and some person go to temple on that day, which may be reason of less arrival of patients.

Friday as well as Saturday were found second and third highest respectively for Friday we have not explanation whereas Saturday is the key of the week, Saturday is closing day for some people and it may due to holiday for the next day (Sunday) that's why most of people like to visit on Saturday. Maximum number of the arrival of patient were reported for General Medicine and followed by General Surgery whereas lowest numbers of arrival were reported for the TB Chest department (Category) during study period.

Average number of total arrival according to day of week is given in the figure 3. Lowest reporting day was found Sunday due to closing day of hospital. Number of arrival as outpatient is considered between Monday and Friday (OPD timing 9:00am to 4:00pm). Apart from timing (from 9:00am to 4:00pm) including holidays of the hospital, arrival of patient are considered as Emergency patient and its reporting is in Emergency department.

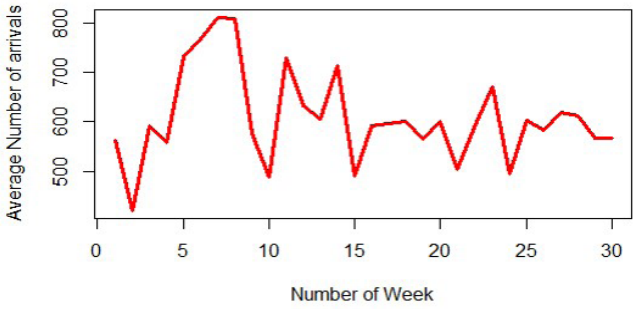

Figure 4: Weekly arrival total over 30-weeks study period.

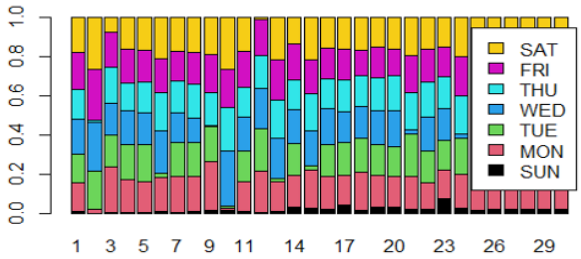

Figure 5: Weekly arrival total over 30-weeks study period.

A weekly arrival total over 30 week study period is presented in figure 4 and its proportional allocations is indicated in figure 5. It is observed that within a week, Sunday has the lowest number of arrivals; it is due to closing day of hospital as explained above. Figure 4 is roughly consistent with that Poisson property, except for week 2, 6 and 7, which are about lowest for week 7 due to holiday or important festival where highest for 6 & 7 due to increase of seasonal disease, which may be due to changing the season from summer to winter.

Models for daily arrivals

Table 2 shows the number of arrivals at the OPD on each day form October, 4, 2019 and February, 29, 2020 (30 weeks). The 30*7=210 daily totals and have mean 608.6. Within the week, Sunday has smallest number of arrivals, which is because of closing day of the hospital. Rest days of week are having little variation in the arrival of patients.

Model

Model for the daily totals have been applied, where first considered a two-factor regression model with Normal residuals for the daily total numbers of arrivals. Detailed about the model can be seen in the section 2.7 & 3.7 of Kutner et al [7]. The daily total numbers of arrivals is represented as

$$T(w,d) = A + Bw + Cd + N(0,\sigma^2) \qquad (1)$$

Table 2: Number of arrivals at the OPD on each day (30 weeks).

Week	SUN	MON	TUE	WED	THU	FRI	SAT	Total	Average
1	35	577	584	703	603	740	697	3939	562.71
2	2	51	580	732	32	768	783	2948	421.14
3	16	977	660	679	768	746	303	4149	592.71
4	18	661	699	673	546	682	624	3903	557.57
5	34	791	965	844	800	843	844	5121	731.57
6	48	943	106	1161	1042	935	1139	5374	767.71
7	23	1053	982	848	923	870	976	5675	810.71
8	57	1012	982	708	962	933	1000	5654	807.71
9	52	1013	721	30	666	786	758	4026	575.14
10	43	45	32	961	756	669	907	3413	487.57
11	54	757	813	883	777	941	887	5112	730.29
12	28	923	959	908	745	813	47	4423	631.86
13	44	644	62	879	835	867	913	4244	606.29
14	154	818	812	859	767	923	657	4990	712.86
15	79	675	84	605	663	587	740	3433	490.43
16	78	692	676	765	641	642	654	4148	592.57
17	180	623	702	658	676	657	674	4170	595.71
18	53	835	722	675	666	558	695	4204	600.57
19	123	649	622	678	663	626	599	3960	565.71
20	129	663	629	792	743	565	687	4208	601.14
21	80	587	766	79	664	672	678	3526	503.71
22	79	568	667	730	733	713	662	4152	593.14
23	350	674	735	763	751	717	700	4690	670.00
24	84	609	645	59	680	698	692	3467	495.29
25	59	736	607	716	706	703	698	4225	603.57
26	82	683	678	671	690	614	666	4084	583.43
27	80	730	695	686	628	744	768	4331	618.71
28	95	772	753	766	716	626	565	4293	613.29
29	74	710	659	696	710	524	597	3970	567.14
30	85	720	645	644	609	638	633	3974	567.71
	2318	21191	19242	20851	21161	21800	21243	127806	
Average	77.27	706.37	641.40	695.03	705.37	726.67	708.10	4260.20	
SD	65.31	225.59	254.12	245.13	165.32	119.73	199.88	651.75	

Where w represents the week and d is the day of week (DoW), and $N(0,\sigma^2)$ is the normal random variable. In other way, it can be say that its residuals are assumed to the normally distributed with mean zero and variance σ^2, where A B and C are constants. The week and the DoW are two factors, so we have w_i's as indicators for each week, d_j's as indicators for each day-of week and B_i's & C_j's accordingly. A gives the average total number of arrivals for study period when model (1) is considered redundancy, since $\sum w_i = 1, \sum d_j = 1$, we set $\sum B_i = 0$ and $\sum C_j = 0$.

In the table 3, results obtained from (ANOVA) analysis of variance for model (1) is presented. It has been observed that both day of week (DoW) is highly significant at 1 & 5 percent levels of significance whereas week is significant at 5 percent of level of significance. It may be concluded that number of arrivals of patients are differ according to the day of week whereas, there is less differences on arrivals of OPD patients according to week. From the residuals, estimated error variance is $\hat{\sigma}^2 = 33459$ and variance ratio is 54.94.

The model (1) is fitted almost well except few outliers by observing that the residuals are almost consistent with normal distribution, it can be seen from the figures 6&8, where histogram, fitted, QQ and factor levels plots of the studentized residuals are presented.

However, after obtained results from table 3, we would prefer the single factor model with only the DoW as single factor, because DoW is found significantly different and whereas week effect is not significantly differ. Therefore estimates of daily totals of arrival of patients can be generated from forecasting. Hence, instead of model (1), single factor model for the total number of arrivals is represented as

$$T(d) = A + Cd + N(0, \sigma^2) \qquad (2)$$

Where again d is the day of week (DoW), and $N(0, \sigma^2)$ is the normal random variable, in the other way, it can be say that its residuals are assumed to the normally distributed with mean zero and variance σ^2. While A and C are constants.

Table 4 indicates that the estimated coefficients for model (2), the coefficients d_j quantify the increasing and decreasing and increasing trend of the daily total arrival within week. All day of week were found significant except two days (Tuesday & Wednesday). Figure 6 shows the histogram for the residuals.

Table 3: ANOVA Table (for two-factor model).

Source of Variation	Sum of Square	Df	MSS	F-Statistics	P-value
Week	1759791	29	60682	1.8136	0.0104
DoW	10008713	6	1668119	49.8556	0.0000
Residuals	5821867	174	33459		

Table 4: Regression coefficients for the model 2.

Coefficients	Estimate	SE	P-value
A	608.6	33.8	0.0000
C.Sun	-531.33	35.8	0.0000
C.Mon	97.77	35.8	0.00610
C.Tue	32.80	35.8	0.3536
C.Wed	86.43	35.8	0.01514
C.Thu	96.77	35.8	0.0066
C.Fri	11.80	35.8	0.0009
C.Sat	99.50	35.8	0.0052

Dependence among daily totals and residuals

We also examined the dependence among the residuals in the single-factor model. We first directly estimated the autocorrelation function and found the first seven coefficients were all positive. ARMA (p, q) models are applied for the daily totals for various p and q with p=7 being a natural choice, but it was not found satisfactory results using ARMA model.

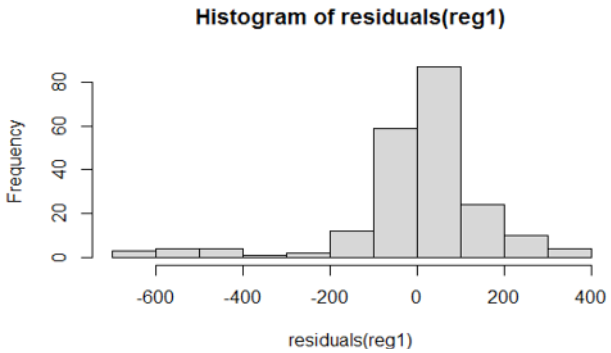

Figure 6: Histogram of residuals.

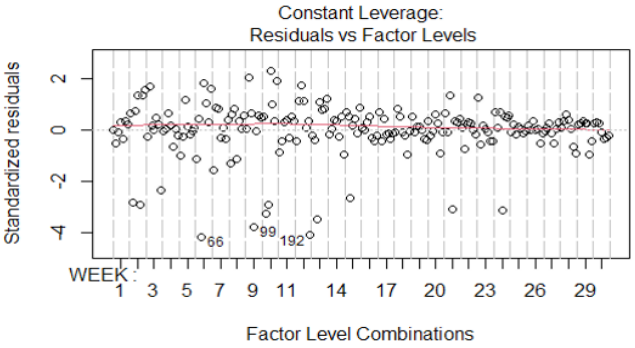

Figure 7: Influence graph of fitted model.

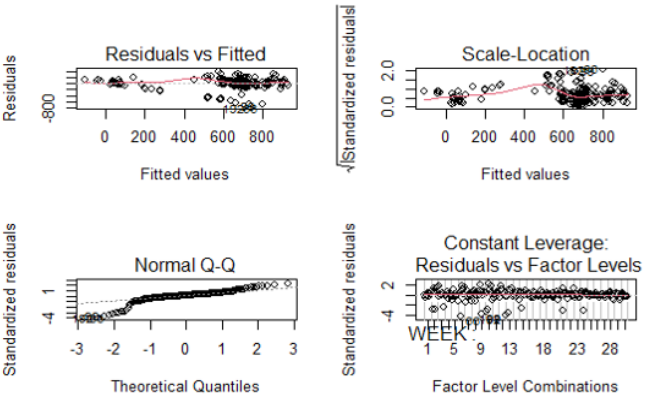

Figure 8: Fitted, QQ and factor levels plots for model 1.

Conclusions

A stochastic model has been applied and studied based on number of arrival of patients in NIIMS hospital. Pattern of arrival of patients were discussed graphically. A two factor and one factor ANOVA table have been discussed for the arrival of outpatients (OPD). Days of week were found statistically significant whereas weeks of study period were found insignificant. Therefore, it can be concluded that there is no significant difference among 30 weeks (study period) and days of week are significantly difference.

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