ISSN: 0975 -8542

Journal of Global Pharma Technology

Available Online at: www.jgpt.co.in

RESEARCH ARTICLE

Modeling of the Effect of Socio-Economic Factors on the Accessibility of Medical and Pharmaceutical Care to the Population (on the Example of Sudan)

Ievtushenko Olena M[1]*, Pestun Irina V[2], Mnushko Zoya M[3], Velma Svitlana V[4], Abuzayid Osama Mohamed Nur Ahmed[5]

1. *Department of Pharmaceutical Marketing and Management National University of Pharmacy, Ukraine.*
2. *Department of Pharmaceutical Marketing and Management; National University of Pharmacy; Ukraine.*
3. *Department of management and economics in family medicine, Kharkiv Medical Academy of Postgraduate Education, Ukraine.*
4. *Department of Pharmacoinformatics National University of Pharmacy, Ukraine.*
5. *Department of Pharmaceutical Marketing and Management; National University of Pharmacy.*

***Corresponding Author: Ievtushenko Olena M**

Abstract

Introduction. The availability of pharmaceutical care is closely connected with the health care system and may be influenced by many factors. The heterogeneity of factors determines the need for their ranking and selection, determining the degree of their mutual influence on each other and on the level of morbidity in the country. The purpose. The aim of the study was the modeling of the availability of medical and pharmaceutical care (for example, Sudan). Materials & Methods. For the analysis, the following factors were selected: share of the state's population in the total population of Sudan, share of the state's area, share of doctors in the total employed population of Sudan, territorial accessibility of medical care, growth rates of the pharmacy network in the state, territorial accessibility of pharmaceutical care, share of expenditures on medicines in the subsistence minimum of Sudanese. To determine the degree of influence of these factors on the incidence rate, correlation and regression analysis was used; the models obtained were tested for adequacy, including the normal distribution of residuals. Research results and discussion. As a result of the study, a number of models were obtained, of which the optimal one was chosen according to the corrected coefficient of determination. It was revealed that the main accessibility factors affecting the incidence of infectious diseases are the territorial accessibility of pharmaceutical care, the share of drug costs in the subsistence minimum of Sudanese, and the growth rate of the pharmacy chain. Conclusions. In accordance with the proposed model, it is possible to determine not only the level of morbidity, but also to simulate the level of accessibility of pharmaceutical care to the population of a separate municipality, to develop, based on the analysis performed, certain organizational, administrative or legislative measures.

Keywords: *Pharmacy, Accessibility, Medical care, Pharmaceutical care, Modeling, African countries, Sudan.*

Introduction

Availability of medicinal care is one of the main factors that affects the incidence and mortality in any country, the possibility of using rational therapy and, ultimately, the nation health. In turn, accessibility itself is also determined by a number of components, including: the availability and territorial accessibility of hospitals, pharmacies, the availability of qualified specialists who can provide medical and pharmaceutical care [1, 2, 3, 4], the physical availability of medicines on the local pharmaceutical market or outside market turnover (in the case of hospital care) [5,6], population size, morbidity, mortality, the structure and ratio of nosologies, the level and structure of income, the accessibility of health insurance systems in the country.

This issue is particularly relevant in African countries and, in particular, in Sudan, where military actions are carried out for a long time, the infrastructure has been destroyed [7], which reduces the physical accessibility of medical and pharmaceutical care, there is no access to clean drinking water, which provokes outbreaks infectious diseases, there is a shortage of medical and pharmaceutical personnel [8], the level of skills of existing specialists is insufficient. The bulk of the population lives below the poverty line, which leads to a low level of economic affordability of certain types of assistance.

A large territory, low population density, an insufficient level of people education, provoking misunderstanding and rejection of the importance of preventive measures, the meager state budget aggravates the existing problems. Selected theoretical and practical questions about the factors affecting the activities of health facilities in African and other countries are being worldwide investigated [9].

The management of the health care system and the pharmaceutical industry in African countries are covered in the regular reports of the World Health Organization [10] and other literary sources [11-17], laid down in the UN Millennium Development Goals Program [18]. Despite the attention of the world community to this problem, publications regarding research in African countries and, in particular, in Sudan, the accessibility of drug supply and its dependence on various external factors are irregular.

Therefore, the development of approaches to determining the degree of mutual influence of factors affecting the level of medical and pharmaceutical care will be relevant. The aim of the study was to model the accessibility of medical and pharmaceutical care (for example, Sudan). To achieve the goal, the following tasks were solved: to determine the criteria for accessibility of drug assistance to the population of the municipality, and also to build an optimal mathematical model of the dependence of the incidence rate on the accessibility of medical and drug assistance to the population of administrative and territorial units.

Materials & Methods

As a base for the study [19-22], the states of Sudan with stable development (on the territory of which military operations are not conducted) were chosen. In this country, the highest rates of morbidity and mortality are characteristic of infectious diseases; therefore, it is advisable to carry out modeling using morbidity indicators with this particular nosology (ICD-10 class “Some infectious and parasitic diseases”).

The incidence rate was chosen as a resultant factor. Under this concept was meant the total incidence (on appeal ability, prevalence, pain), which is usually calculated in accordance with the formula: (the number of all primary diseases (acute and chronic) identified in a given year) / average annual population) x 1000. In the case of Infectious diseases incidence may be used for infectious diseases, however, the above indicator is used in Sudan’s medical statistics. The following variables were selected for analysis and determination of dependence.

- The proportion of the state’s population in the total population of the Sudan;
- The proportion of state space in the total area of Sudan;
- The proportion of doctors in the total employment of the Sudan;
- Territorial accessibility of medical care, which will be expressed by the following ratio:

$$\frac{\text{Number of hospitals in the state}}{\text{Per 1 resident in the state}} : \frac{\text{Number of hospitals in Sudan}}{\text{Per 1 inhabitant of Sudan}}$$

- Growth rate of the pharmacy chain in the state (chain growth / decline indices, ki);
- The territorial accessibility of pharmaceutical care, which will be expressed by the following relationship:

$$\frac{\text{Number of pharmacies in the state}}{\text{Per 1 resident in the state}} : \frac{\text{Number of pharmacies in Sudan}}{\text{Per 1 inhabitant of Sudan}}$$

- The share of drug costs in the subsistence minimum of Sudanese.

The input data chosen for the modelling are represented in Table 1. The next stage was the construction of correlation matrixes (correlation coefficients were calculated for all pairs of variables), analyzes of the resulting matrixes were carried out, which allowed to draw conclusions about the existence of a relationship between certain variables. The significance of the obtained correlation values was analyzed. The adequacy of each constructed model was estimated by the value of the determination coefficient R^2, which is the square of the multiple correlation coefficients Multiple R. The closer it is to 1, the higher the adequacy of the model. In addition, the analysis of the model adequacy included checking the residuals correspondence with the normal distribution. The significance of the regression equation parameters was formally checked by comparing the calculated and tabular Fisher criteria. With a positive response ($F_{tabl} < F$), the model was considered significant.

Table 1: Input data for modeling the dependence of the accessibility of pharmaceutical care in Sudan on socio-economic factors

№	States	Share of state population in total population of Sudan	Proportion of state in total area of Sudan	Share of doctors in the total employment of the Sudan	Territorial accessibility of medical care	Growth rate of the pharmacy chain in the state (coefficient of chain growth / decline, ki)	Territorial accessibility of pharmaceutical care	Share of drug costs in the subsistence minimum of Sudanese	Incidence rate
1	**South Darfur**	0,13	0,07	0,000006	0,89	1,38	0,47	0,0107	3,72
2	**West Darfur**	0,02	0,04	0,000002	1,03	1,11	0,71	0,0107	5,64
3	**Central Darfur**	0,02	0,02	0,000001	0,81	0,98	0,70	0,0063	6,78
4	**North Darfur**	0,06	0,16	0,000010	0,92	1,37	0,51	0,0098	3,85
5	**Southern Kordofan**	0,05	0,08	0,000004	0,72	1,06	0,47	0,0078	5,98
6	**Northern Kordofan**	0,08	0,12	0,000017	0,85	1,28	0,94	0,0082	4,50
7	**Blue Nile**	0,03	0,02	0,000007	0,79	1,04	0,33	0,0057	16,34
8	**White Nile**	0,06	0,02	0,000012	0,95	0,99	0,46	0,0071	6,34
9	**Sennar**	0,04	0,02	0,000012	0,51	0,95	0,16	0,0044	17,54
10	**El Gezira**	0,12	0,01	0,000046	0,96	1,24	0,78	0,0083	10,48
11	**Khartoum**	0,18	0,01	0,000126	1,45	1,71	2,58	0,0083	2,92
12	**Cassala**	0,06	0,02	0,000013	0,80	1,08	0,86	0,0080	5,54
13	**Al-Gedaref**	0,05	0,04	0,000014	1,08	1,23	0,50	0,0079	8,51
14	**Red Sea**	0,04	0,12	0,000008	1,19	1,41	1,33	0,0085	4,18
15	**River Nile**	0,04	0,06	0,000013	1,24	1,37	0,91	0,0066	9,82
16	**Northern State**	0,02	0,18	0,000009	0,71	1,23	0,60	0,0076	11,51

Research Results and Discussion

To identify the most influential factors and determine the extent of their influence on each other, a correlation-regression analysis of the input data was conducted and the relationship between "Incidence rate" variable and the above factors was revealed. For this, a correlation matrix was constructed (the correlation coefficients for all pairs of variables were calculated) (Table 2).

Table 2: Correlation Matrix

	Means	Share of state population in total population of Sudan	Proportion of state in total area of Sudan	Share of doctors in the total employment of the Sudan	Territorial accessibility of medical care	Growth rate of the pharmacy chain in the state (coefficient of chain growth /	Territorial accessibility of pharmaceutical care	Share of drug costs in the sub-sistence minimum of Sudanese

						decline, ki)		
Percentage of state population in total population of Sudan	0,062500							
State share in total Sudan	0,062500	-0,235604						
Share of doctors in the total number of employed people in Sudan	0,000019	0,803937	-0,300542					
Territorial accessibility of medical care	0,930592	0,441399	-0,125738	0,598459				
Growth rate of the pharmacy chain in the state	1,214375	0,664642	0,282820	0,657707	0,765633			
Territorial accessibility of pharmaceutical care	0,768608	0,609800	-0,094427	0,840428	0,776848	0,764911		
Share of drug costs in the subsistence minimum of Sudanese	0,007874	0,357166	0,317101	0,056323	0,362580	0,487002	0,214025	
Incidence rate	7,729164	-0,404677	-0,204758	-0,213840	-0,508316	-0,511118	-0,500042	-0,750347

The analysis of the obtained correlation matrix allows conclude about a relationship between "Incidence rate" variable and the other variables. Thus, the variable "Share of drug costs in the subsistence minimum of Sudanese" shows a high dependence. Significant dependencies are shown by the variables "Territorial accessibility of pharmaceutical care", "Territorial accessibility of medical care" and "Growth rates of the pharmacy chain in the state"; moderate dependence - "Proportion of the state's population in the total population of Sudan." To estimate the relationship between variables, one needs to know both the correlation coefficient value and its significance. The level of significance calculated for each correlation is the main source of information about the correlation reliability. Check the significance of the obtained correlation coefficients (Table 3).

Table 3: Analysis of the significance of the obtained correlation coefficients Extended Correlation Matrix

	Share of state population in total population of Sudan	Proportion of state in total area of Sudan	Share of doctors in the total employment of the Sudan	Territorial accessibility of medical care	Growth rate of the pharmacy chain in the state (coefficient of chain growth / decline, ki)	Territorial accessibility of pharmaceutical care	Share of drug costs in the sub-sistence minimum of Sudanese
State share in total Sudan	-0,2356						
	p=0,380						
Share of doctors in the total number of employed people in Sudan	0,8039	-0,3005					
	p=0,000	p=0,258					
Territorial accessibility of medical care	0,4414	-0,1257	0,5985				
	p=0,087	p=0,643	p=0,014				
Growth rate of the pharmacy chain in the state	0,6646	0,2828	0,6577	0,7656			
	p=0,005	p=0,289	p=0,006	p=0,06			
Territorial accessibility of pharmaceutical	0,6098	-0,0944	0,8404	0,7768	0,7649		

care	p=0,012	p=0,728	p=0,000	p=0,191	p=0,23		
Share of drug costs in the subsistence minimum of Sudanese	0,3572	0,3171	0,0563	0,3626	0,4870	0,2140	
	p=0,174	p=0,231	p=0,836	p=0,168	p=0,056	p=0,426	
Incidence rate	-0,4047	-0,2048	-0,2138	-0,5083	-0,5111	-0,5000	-0,7503
	p=0,120	p=0,447	p=0,426	p=0,044	p=0,043	p=0,049	p=0,001

An analysis of the extended correlation matrix made it possible to conclude that the above dependencies are significant. Further, the regression analysis was conducted to determine the dependence function of "Incidence rate" variable on predictor variables. We choose 4 variables as predictors: x1 - "Territorial accessibility of medical care", x2 - "Growth rates of the pharmacy chain in the state", x3- "Territorial accessibility of pharmaceutical care", x4 – "Share of drug costs in the subsistence minimum of Sudanese". The remaining variables of the input data have weak correlation dependence with "Incidence rate" variable and their correlation coefficients are not significant (p-value > 0.05). Before the start of multiple regression analysis, paired regressions were constructed for each predictor and input data were checked for the presence of outliers. The result of the regression analysis for the variable x1 "Territorial accessibility of medical care" is presented in Fig. 1.

N=16	Regression Summary for Dependent Variable: y R= ,50019157 R²= ,25019161 Adjusted R²= ,19663386 F(1,14)=4,6714 p<,04848 Std.Error of estimate: 3,9386					
	b*	Std.Err. of b*	b	Std.Err. of b	t(14)	p-value
Intercept			16,0343	3,96675	4,0421	0,00121
x1	-0,50019	0,23142	-8,80421	4,07347	-2,16135	0,04848

Figure 1: Regression analysis result for variable x1

The resulting regression coefficients are significant (p-value < 0.05). Therefore, the equation of the pair regression for the variable x1 is:

$$Y = 16{,}034 - 8{,}804 \cdot x1,$$

Where Y is "Incidence rate" variable;

X1 – "Territorial accessibility of medical care" variable.

The Scatter plot for the variable x1 (Fig. 2) also indicates the presence of a negative relationship between the variables Y and x1.

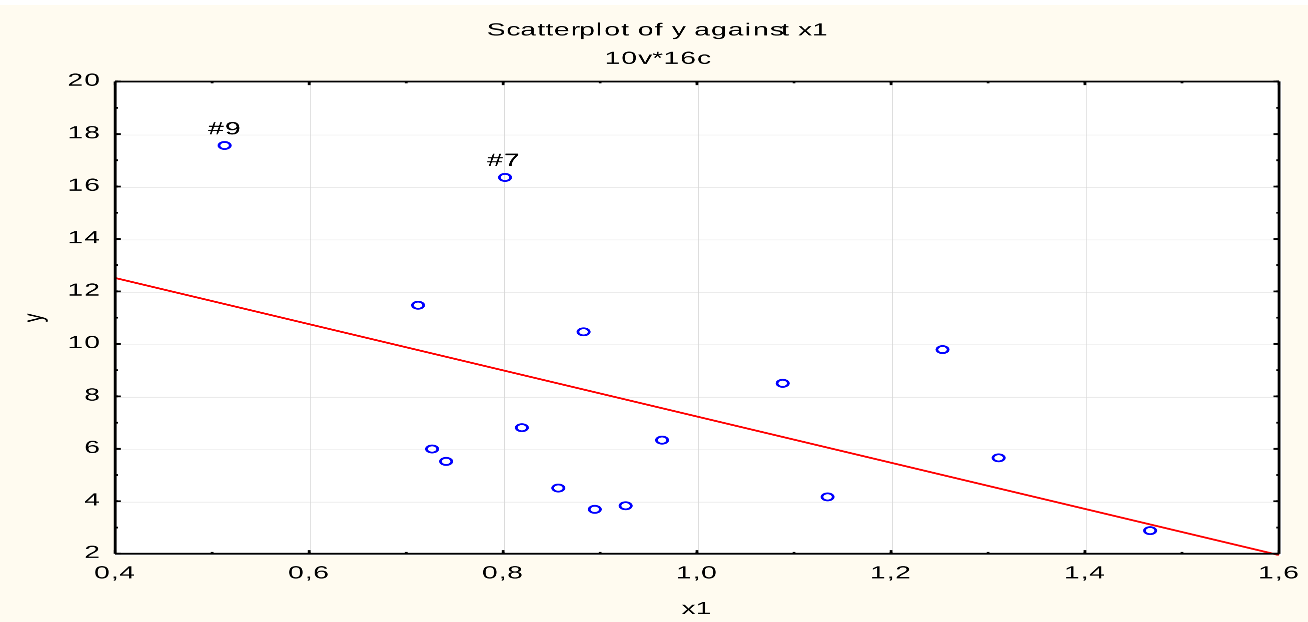

Figure 2: Scatterplot for variable x1 "Territorial accessibility of medical care"

The result of the regression analysis for the variable x2 "Growth rates of the pharmacy chain in the state" is presented in Fig. 3.

	Regression Summary for Dependent Variable: y R= ,52084090 R= ,27127525 Adjusted R²= ,21922348 F(1,14)=5,2116 p<,03858 Std.Error of estimate: 3,8828					
N=16	b*	Std.Err. of b*	b	Std.Err. of b	t(14)	p-value
Intercept			22,910(	6,72067:	3,4090:	0,00423(
x2	-0,52084:	0,22814(	-12,599(	5,51883:	-2,2829(	0,03858(

Figure 3: Regression analysis result for variable x2

The standardized (b*) and non-standardized (b) regression coefficients (Fig.4) are significant (p-value < 0.05). Therefore, the equation of the pair regression for x2 is:

Y = 22, 91 – 12, 6·x2,

Where Y is "Incidence rate" variable;

X2 – "Growth rates of the pharmacy chain in the state" variable.

Similarly, a scatter plot was constructed for the variable x2, which also indicates the presence of a negative relationship between the variables Y and x2.

The result of the regression analysis for the variable x3 "Territorial accessibility of pharmaceutical care" is presented in Fig.4.

	Regression Summary for Dependent Variable: y R= ,50004159 R= ,25004159 Adjusted R²= ,19647313 F(1,14)=4,6677 p<,04856 Std.Error of estimate: 3,9390					
N=16	b*	Std.Err. of b*	b	Std.Err. of b	t(14)	p-value
Intercept			10,7619:	1,71470:	6,2762(	0,00002(
x3	-0,50004:	0,23144(	-3,9457(	1,82633:	-2,1604(	0,04855(

Figure 4: Regression analysis result for x3

The standardized (b*) and non-standardized (b) regression coefficients (Fig. 5) are significant (p-value < 0.05). Therefore, the equation of the pair regression for x3 is:

Y = 10, 76 – 3, 9·x3,

Where Y is "Incidence rate" variable;

X3 – "Territorial accessibility of pharmaceutical care" variable.

The result of the regression analysis for variable x4 "The share of drug costs in the subsistence minimum of Sudanese" is shown in Fig.5.

	Regression Summary for Dependent Variable: y R= ,75034725 R= ,56302099 Adjusted R²= ,53180820 F(1,14)=18,038 p<,00081 Std.Error of estimate: 3,0068					
N=16	b*	Std.Err. of b*	b	Std.Err. of b	t(14)	p-value
Intercept			23,312:	3,74529(	6,2244:	0,00002:
x4	-0,75034:	0,17667:	-19,791:	4,65997:	-4,24713	0,00081:

Figure 5: The result of regression analysis for x4

The obtained regression coefficients are significant (p-value < 0.05) and the pair regression equation for variable x4 is:

Y = 23,3 – 19,79·x4,

Where Y is "Incidence rate" variable;

X4 – "The share of drug costs in the subsistence minimum of Sudanese" variable.

At the next stage, a multiple regression analysis was conducted to find the dependence function of "Incidence rate" variable on all predictor variables: x1 "Territorial accessibility of medical care", x2 "Growth rates of the pharmacy chain in the state", x3 "Territorial accessibility of pharmaceutical care", and x4 "The share of drug costs in the subsistence minimum of Sudanese".

At the first step, we will conduct a regression analysis to find the functional dependence Y = f(x1, x2, x3, x4). The results of the regression analysis for the variables x1, x2, x3, x4 are presented in Fig.6.

Statistic	Summary Statistics; DV: y (1.sta) Value
Multiple R	0,8514753
Multiple R²	0,7250102
Adjusted R²	0,62501393
F(4,11)	7,2503716
p	0,004112717
Std.Err. of Estimate	2,6908803

N=16	Regression Summary for Dependent Variable: y R= ,85147532 R²= ,72501022 Adjusted R²= ,62501394 F(4,11)=7,2504 p<,00411 Std.Error of estimate: 2,6909					
	b*	Std.Err. of b*	b	Std.Err. of b	t(11)	p-value
Intercept			17,8154	5,805693	3,06861	0,010686
x1	0,182874	0,249795	3,2189	4,396800	0,73210	0,479417
x2	0,311292	0,260258	7,5300	6,295556	1,19609	0,256808
x3	-0,628857	0,279248	-4,9622	2,203512	-2,25196	0,045732
x4	-0,885138	0,231225	-23,3468	6,098916	-3,82803	0,002804

Figure 6: The results of regression analysis for all predictors (x1, x2, x3, x4)

The "Regression Summary" table contains standardized (b*) and non-standardized (b) regression coefficients, their standard errors and p-levels. The b* values make it possible to compare the contributions of each predictor to the predicted result. Thus, the dependent variable Y "Incidence rate" is made more by the variable x4 "Share of drug costs in the subsistence minimum of Sudanese", and the smaller contribution is x1 "Territorial accessibility of medical care".

It should be noted that not all the obtained regression coefficients are significant:

- For the variable x1 $p = 0.4794 > 0.05$;
- For the variable x2 $p = 0.2568 > 0.05$.

The regression coefficient is called significant if there is a high enough probability that its true value is non-zero. Otherwise, the factor corresponding to this regression coefficient is recommended to be excluded from the model, and the quality of the model will not deteriorate.

Thus, the regression equation:

Y = 17, 8 + 3, 2·x1 + 7, 5·x2 – 4, 9·x3 – 23, 3·x4

Should be replaced by equivalent quality regression equation

Y = 17, 82 – 4, 96·x3 – 23, 35·x4,

Where Y is "Incidence rate" variable;

X1-"Territorial accessibility of medical care" variable;

X2-"Growth rates of the pharmacy chain in the state" variable;

X3-"Territorial accessibility of pharmaceutical care" variable;

X4-"Share of drug costs in the subsistence minimum of Sudanese" variable.

The significance of the regression equation parameters is formally verified by comparing the calculated and tabular Fisher criteria. If the answer is positive ($F_{tabl} < F$), the model is significant. In this case, the value of Fisher criterion $F(4,11) = 7.25$; and p-level = 0.0041 < 0.05, so its significance level is quite high. The tabular Fisher criteria $F_{tabl}(4,11) = 3.35669$.

The adequacy of the constructed model is estimated by the value of the determination coefficient R2 (Multiple R2 = 0.725), which is the square of the coefficient of multiple correlation (Multiple R = 0.851). The closer it is to 1, the higher the adequacy of the model.

In addition, the model adequacy analysis includes residual analysis. The deviation of an each point from the regression line (from the predicted value) is called the residual. The residuals show you how far away the actual data points are from the predicted data points (using the equation).Normality test.

In multiple regression, it is assumed that the residuals (predicted values minus observables) are normally distributed (i.e. obey the law of normal distribution). Again, although most of the tests (especially the F-test) are quite robust (stable) with respect to deviations from this assumption, it is worth considering the distributions of the variables of interest. Residuals correspond to the normal distribution, since they are located near the normal distribution line (Fig. 7).

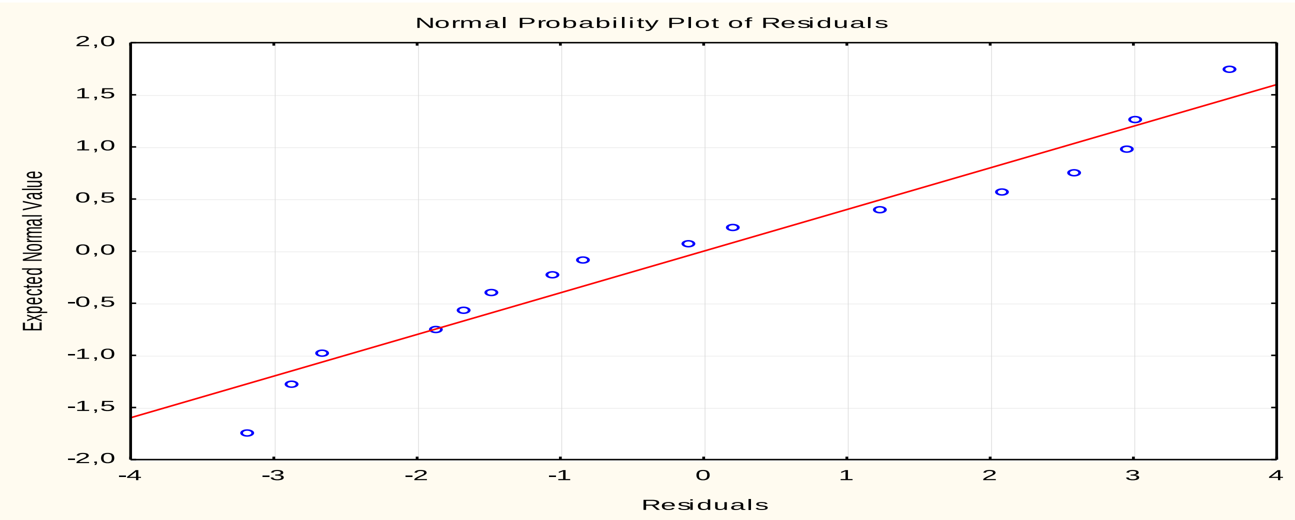

Figure 7: Normality test for residuals of multiple regressions Y = f(x1, x2, x3, x4)

The residuals are independent, because the Durbin-Watson test for determining the independence of residuals shows the value DW = 2.222 (Fig. 8) and the periodicity in the grouping of residuals is not observed (Fig. 9).

	Durbin-Watson d and serial correlation of residuals	
	Durbin-Watson d	Serial Corr.
Estimate	2,22237!	-0,18638!

Figure 8: Verification the independence of residuals (Durbin-Watson test) for multiple regressions Y = f(x1, x2, x3, x4)

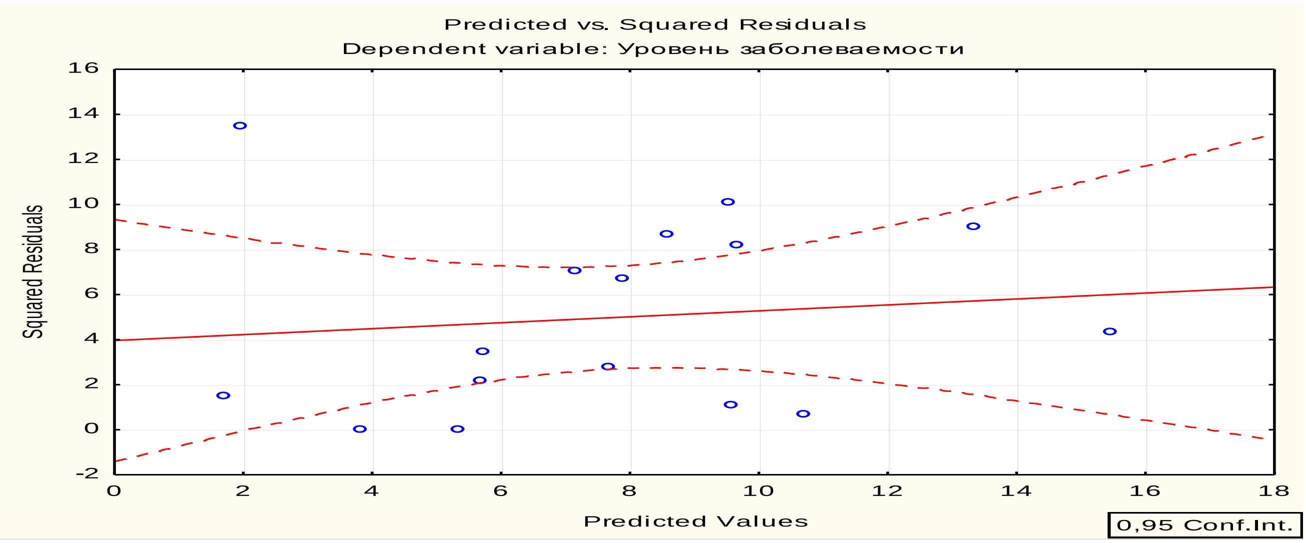

Figure 9: Verification the independence of residuals (residuals graph) for multiple regression Y = f (x1, x2, x3, x4)

Thus, we can conclude that the constructed regression model Y = f(x1, x2, x3, x4) is adequate. At the second step, to build a regression model, we will analyze the predictor variables in more detail: only one variable is completely independent according to the extended correlation matrix (Table 4) – "The share of drug costs in the subsistence minimum of Sudanese." There are noticeable (p> 0.05) correlations between the variables "Territorial accessibility of pharmaceutical care" and "Growth rates of the pharmacy chain in the state", as well as between the variables "Territorial accessibility of pharmaceutical care" and "Territorial accessibility of medical care". Therefore, we choose 3 variables as predictors for the second model: x4 "Share of drug costs in the subsistence minimum of Sudanese", x1 "Territorial accessibility of medical care" and x2 "Growth rates of the pharmacy chain in the state". We will conduct a regression analysis to find the functional dependence Y = f(x1, x2, x4). The results of the regression analysis for the variables x1, x2, x4 are presented in Fig.10.

Statistic	Summary Statistics; DV: y (1.sta) Value
Multiple R	0,77345417
Multiple RI	0,59823135
Adjusted RI	0,49778919
F(3,12)	5,9559785
p	0,0099802361
Std.Err. of Estimate	3,1140805

N=16	Regression Summary for Dependent Variable: y (1.sta) R= ,77345417 R²= ,59823136 Adjusted R²= ,49778919 F(3,12)=5,9560 p<,00998 Std.Error of estimate: 3,1141 b*	Std.Err. of b*	b	Std.Err. of b	t(12)	p-value
Intercept			25,4522	5,453452	4,66717	0,000544
x1	-0,195343	0,213987	-3,4384	3,766521	-0,91287	0,379285
x2	-0,042509	0,240121	-1,0283	5,808439	-0,17703	0,862437
x4	-0,637548	0,235406	-16,8163	6,209184	-2,70829	0,019015

Figure 10: Regression analysis results for the second set of predictors (x1, x2, x 4)

According to the analysis (Fig. 11), the regression equation:

Y = 25,45 – 3,44·x1 – 1,03·x2 – 16,82·x4

Or Y = 25, 45 – 16, 82·x4,

Where Y is "Incidence rate" variable; x1 – "Territorial accessibility of medical care" variable; x2 –"Growth rates of the pharmacy chain in the state" variable; x4 – "Share of drug costs in the subsistence minimum of Sudanese" variable.

The second equation of Y is due to the fact that the regression coefficients for the variables x1 and x2 are not significant, and it is recommended to exclude the factor corresponding to this regression coefficient from the model.

The significance of the regression equation parameters: the value of Fisher criterion F(3,12) = 5.95597; and p-level = 0.0099 < 0.05, so its significance level is quite high. The tabular Fisher criterion F_{tabl} (3, 12) = 3.49029 is less than F-criterion, therefore the model is considered significant.

The adequacy of the constructed model: Multiple R = 0.773.

Also, the model adequacy analysis includes residual analysis.

Normality test. Residuals correspond to the normal distribution, since they are located near the normal distribution line (Fig. 11).

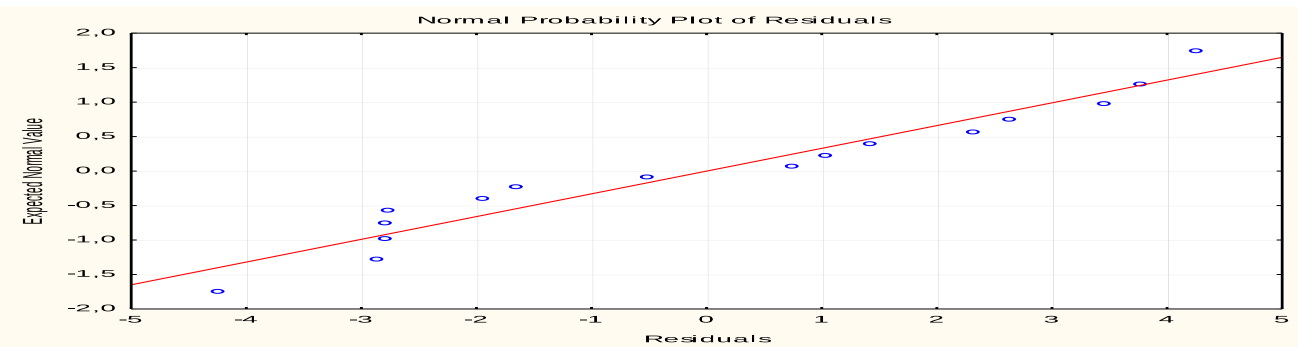

Figure 11: Normality test for residuals of multiple regressions Y = f(x1, x2, x4)

The residuals are independent, because the Durbin-Watson test for determining the independence of residuals shows the value DW = 2.468308 (Fig. 12).

	Durbin-Watson d and serial correlation of residuals	
	Durbin-Watson d	Serial Corr.
Estimate	2,468308	-0,283178

Figure 12: Verification the independence of residuals (Durbin-Watson test) for multiple regressions Y = f(x1, x2, x4)

The absence of periodicity in the grouping of residuals also indicates the independence of the residuals (Fig. 13).

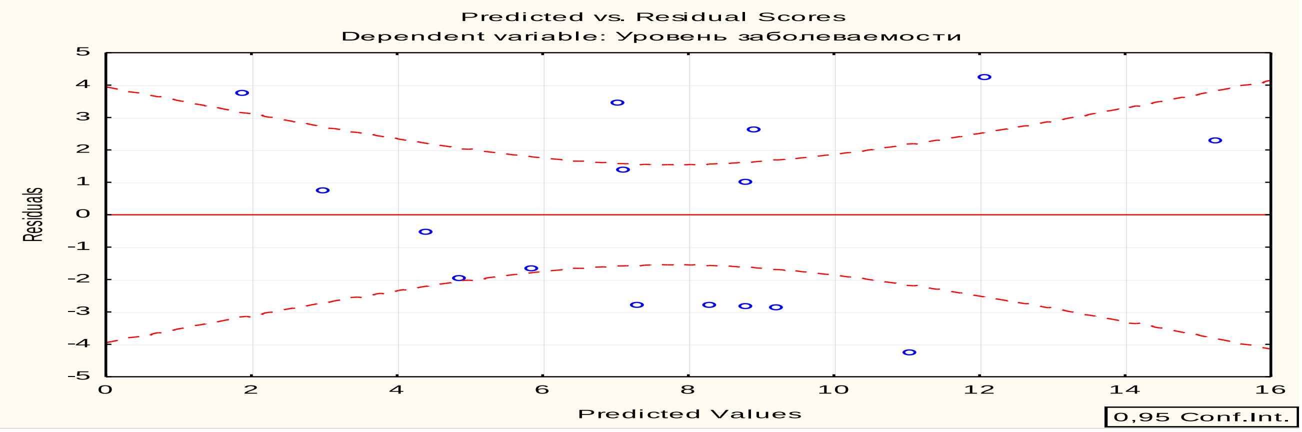

Figure 13: Verification the independence of residuals (residuals graph) for multiple regression Y = f (x1, x2, x4)

Thus, we can conclude that the regression model Y = f(x1, x2, x4) is also adequate. At the third step, we will construct a nonlinear model. As a rule, all the dependencies found in the world around us are non-linear. Therefore, when modeling the relationships inherent in the processes and phenomena under study, along with linear regression models, it is advisable to consider non-linear regression models. So, we will build two non-linear models with such predictors: a) in the first case we choose 3 variables: x4 "Share of drug costs in the subsistence minimum of Sudanese", x1 "Territorial accessibility of medical care" and x2 "Growth rates of the pharmacy chain in the state"; b) in the second case we use all 4 predictors: x1 "Territorial accessibility of medical care", x2 "Growth rates of the pharmacy chain in the state", x3 "Territorial accessibility of pharmaceutical care", x4 "Share of drug costs in the subsistence minimum of Sudanese ". These models are adequate. To select the best model, compare the resulting regressions by adjusted determination coefficient (Adjusted R^2) - the best regression has a higher determination coefficient (Table 4).

Table 4: Summary of Analysis Results

Regression	Adjusted Determination Coefficient
Y = 17,8 + 3,2·x1 + 7,5·x2 – 4,9·x3 – 23,3·x4 or Y = 17,82 – 4,96·x3 – 23,35·x4	0,625
Y = 25,45 – 3,44·x1 – 1,03·x2 – 16,82·x4 or Y = 25,45 – 16,82·x4	0,498
$Y = 13{,}7 + 52{,}2 \cdot x2^2 - 6{,}3 \cdot x3 + 82{,}5 \cdot x4^2 - 136{,}5 \cdot x2 \cdot x4$	0,823
Y = 18,9·x1 + 54,75·x2 – 71,7·x4 – 48,26·x1·x2 + 47,65·x1·x4	0,691

The best model from the statistical point of view is non-linear multiple regression ($Y = 13, 7 + 52, 2 \cdot x2^2 - 6, 3 \cdot x3 + 82, 5 \cdot x4^2 - 136, 5 \cdot x2 \cdot x4$). In accordance with the selected factors, it is possible to model the level of accessibility of pharmaceutical care to the population of a separate municipality, compare the indicators of accessibility of drug provision of different territories with each other and model the potential effects of accessibility of medical and pharmaceutical care on morbidity, develop organizational measures to increase the accessibility of pharmaceutical care.

Conclusion

In accordance with the selected factors, it is possible to determine not only the incidence rate, but also to model the level of accessibility of drug assistance to the population of a separate municipality, compare the indicators of accessibility of drug provision of different territories with each other and model potential effects on the accessibility of medical and pharmaceutical care to the population analysis of organizational measures to increase the accessibility of drug care.

Acknowledgments

The authors would like to thank all participants for their contribution to this study.

Contributing Authors

The research was conducted by the authors without financial support from any organizations or funds.

Conflict of Interest

The authors declare that they have no conflict of interest to disclose.

References

1. Roshchin GE (2013) Mezhdunarodnye korporatcii v Afrike [International Corporations in Africa]. Aziia i Afrika segodnia, 12:30-3.
2. Organizatcii a zdravookhraneniia v razvivaiushchikhsia stranakh [Health Organization in Developing Countries]. Available at http://helpiks.org/2-34536.html [Accessed on March 22, 2019].
3. Panfilova H, Bogdan N, Gala L, Simonian L, Tsurikova O (2018) Analysis of Ukrainian pharmaceutical market retail segment development. Journal of Global Pharma Technology, 10(3):191-9.
4. VOZ Imeetsia li v bolshinstve stran dostatochnoe kolichestvo rabotnikov zdravookhraneniia [WHO. Are there enough health workers in most countries?]. Available at http://www.who.int/features/qa/37/ru/ [Accessed on March 22, 2019].
5. WHO The African Regional Health Report. Available at http://www.who.int/mediacentre/news/releases/2006/pr68/ru/ [Accessed on March 22, 2019].
6. WHO (2015) Eastern Mediterranean Region. Framework for health information systems and core indicators for monitoring health situation and health system performance. 2015. Available at http://applications.emro.who.int/dsaf/EMROPUB_2015EN1904.pdf?ua=1&ua=1 [Accessed on March 22, 2019].
7. Sudan:sereznye problemy s meditcinoi [Sudan: serious problems with medicine]. Available at http://peopleandcountries.com/article-784-1.html [Accessed on March 22, 2019].
8. Medicine Prices, Availability and Affordability in Sudan. Available at http://haiweb.org/wp-content/uploads/2015/07/Sudan-Report-Pricing-Surveys.pdf [Accessed on March 22, 2019].
9. Bashaar M, Hassali MA, Saleem F, ALrasheedy AA, Thawani V, Babar Z-U-D (2017) Efficacy of international approaches to medicine price regulation and control: A scoping review. Journal of Applied Pharmaceutical Science, 7(04):227-41. Doi: 10.7324/JAPS.2017.70434.
10. WHO. Country cooperation strategy. Sudan. 2017. Available at https://apps.who.int/iris/bitstream/handle/10665/136885/ccsbriefsdnen.pdf;jsessionid=BD7B54020BBC36FEBA7EAD23ECCBEC94?sequence=1 [Accessed on March 22, 2019].
11. Republic Sudan National Health Sector Strategic Plan II (2012-16) Available at http://www.nationalplanningcycles.org/sites/default/files/planning_cycle_repository/sudan/sudan_national_health_sector_strategic_plan_nhssp_2012-2016.pdf [Accessed on March 22, 2019].
12. UNICEF Annual Report for Sudan (2017) Khartoum: National Health Information Center, 3.
13. Pristianty L, Soemiati F (2014) Mathematic model of pharmaceutical care to encourage client to be rational in use nsaids by self medication. International Journal of Pharmacy Practice & Drug Research, 4(2):196-202.

14. Salah Ibrahim Kheder, Hassan Mohamed Ali (2014) Evaluating medicines prices, availability, affordability and price components in Sudan. Sudan Medical Monitor, 9(1):19-30. Doi: 10.4103/1858-5000.144655.

15. Strengthening health systems to improve health out comes. Available at http://www.who.int/healthsystems/strategy/everybodys_business.pdf?ua=1 [Accessed on March 22, 2019].

16. Zachariah R, Ford N, Maher D, Bissell K, Van den Bergh R, van den Boogaard W, et al (2012) Is operational research delivering the goods? The journey to success in low-income countries. The Lancet Infectious Diseases, 12(5):415-21. doi: 10.1016/S1473-3099(11)70309-7.

17. Zuma SM (2013) The factors affecting availability of medicines in the free state district health services [dissertation]. Pretoria, Gauteng: University of South Africa 119.

18. Tceli tysiacheletiia v oblasti razvitiia. Doklad (2015 g) [Millennium Development Goals. 2015 Report]. Available at http://www.un.org/ru/millenniumgoals/mdgreport2015.pdf [Accessed on March 22, 2019].

19. Sudan health observatory [database]. Available at http://www.sho.gov.sd/controller/ind_data.php?sm_id=125&mid=109&lid=1 [Accessed on March 22, 2019].

20. Sudan National Health Accounts. Available at https://knoema.ru/WHONHA2019/national-health-accounts?country=1001010-sudan [Accessed on March 22, 2019].

21. BTI Country Report Sudan (2017) Available at https://www.bti-project.org/fileadmin/files/BTI/Downloads/Reports/2018/pdf/BTI_2018_Sudan.pdf [Accessed on March 22, 2019].

22. Economic indicators for over 200 countries. Available at http://ru.theglobaleconomy.com/compare-countries/ [Accessed on March 22, 2019].

