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Influence of Individual Hospital Characteristics on Medicinal Products Replenishment Methods in a Hospital Pharmacy

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Abstract:

Purpose: *The aim of this article is to present the results of the research, the subject of which was to determine the influence of individual hospital characteristics on medicinal products replenishment methods in a hospital pharmacy.*
Design/Methodology/Approach: *In order to answer the stated research questions, a statistical analysis was carried out of the obtained research results on the digitalisation of logistics processes in the pharmacy industry. The hypotheses were verified using Spearman's correlation.*
Findings: *Activities related to the digitization of in-hospital logistics processes can significantly contribute to the support of the treatment process, thanks to the use of appropriate solutions and tools contributing to the streamlining of selected activities performed by medical personnel. There are a number of features that differentiate healthcare entities, such as the size of the hospital, the level of reference, or the use of IT tools.*
Practical Implications: *Hospitals play an important role in the health care system by providing medical services to citizens. The purpose of providing hospital services is primarily the implementation of the treatment process aimed at preserving, saving, restoring or improving the health of patients who use such services.*
Originality value: *The present research, with the verification of hypotheses, was conducted for the first time in this area. The digitalisation of logistics processes in hospitals has not been verified by this research method to this point, in terms of business practice.*

Keywords: *Inventory replenishment, medicinal product management, hospital processes.*

JEL codes: *L15, L86, I15.*

Paper Type: *Research article.*

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1. Introduction

Hospitals play an important role in the health care system by providing medical services to citizens. The purpose of providing hospital services is primarily the implementation of the treatment process aimed at preserving, saving, restoring or improving the health of patients who use such services (Karkowski, 2015). The hospital's logistics system is a complex system, covering the following areas:

- inventory management through the implementation of such activities as purchases, receipts, product inventory level control (including deliveries),
- transport management through the implementation of such activities as the transport of patients to the hospital and the management of patient traffic within the hospital premises and the transport of health care products,
- managing the distribution of products to individual wards and / or patients,
- management of processes related to sterilization and washing (Dembińska-Cyran, 2005).

Activities related to the digitization of in-hospital logistics processes can significantly contribute to the support of the treatment process, thanks to the use of appropriate solutions and tools contributing to the rationalization of selected activities performed by medical personnel (Klimczak and Olszewski, 2014). From the point of view of providing adequate pharmacotherapy to patients, a special role is played by the management of stocks of medicinal products in the form of external supplies and internal supplies.

The scope of external procurement includes, ordering products by the central pharmacy from the supplier, storage, acceptance of the delivery by the central pharmacy. In turn, internal supplies include: ordering products by the branch in a central pharmacy, picking in accordance with the order placed, internal transport and acceptance of delivery by the branch. In this area, significant changes have been observed in recent years, which are related to the implementation of digital solutions in the form of teleinformation systems, in particular the electronization of document circulation and automated data exchange regarding, inter alia, medicinal products.

There are a number of features that differentiate healthcare entities, such as the size of the hospital, the level of reference, or the use of IT tools. The aim of this article is to present the results of the research, the subject of which was to determine the influence of individual hospital characteristics on medicinal products replenishment methods in a hospital pharmacy.

2. Research Methodology

Regardless of the scope of the research, it is advisable to carry out a reliable verification of the obtained data and information. The number of hospitals makes it impossible to verify most of them, therefore the proposed research methodology should include a statistically developed research sample that will guarantee the representativeness of the results. Statistical tools are used to define a typical research sample, which guarantee a specific level of representativeness.

The first very important issue is the appropriate selection of the statistical distribution for the analyses. Taking into account the specificity of the healthcare industry and the scope of logistics processes carried out, it can be assumed that the normal distribution should be used in the tests. This is confirmed by the analyses published in the scientific literature (Blanchard *et al.*, 1990; Näslund, 2002; Iannoni and Morabito, 2006; Engblom *et al.*, 2012; Krzyzaniak, 2017) on the use of statistical tools in the optimization of logistics processes.

According to the theory of estimation in operations research, the minimum research sample that guarantees the representativeness of results is the number n=30. The confidence level should not be less than 85% and the maximum error should not be greater than 18% (Balakrishnan and Basu, 1996). For this reason, the following was adopted as the minimum value for the methodology developed in this article:

- confidence level 95%;
- maximum error 15%.

Table 1 shows the minimum size of the research sample, taking into account the change in the maximum error rate while maintaining a constant confidence level of 95%.

Table 1. *Identification of the minimum size of the research sample*

Population / Maximum error	30	50	100	200	300	400	500	1000	2000	5000	>10000
5%	28	44	79	132	168	196	217	278	322	357	370
10%	23	33	49	65	73	77	81	88	92	94	95
15%	**18**	**23**	**30**	**35**	**37**	**39**	**39**	**41**	**42**	**42**	**43**

Source: *Own research.*

This analysis shows that assuming the maximum error at the level of 15%, the research sample in the size of 43 hospitals should be seen as representative. This research methodology has been verified by the author in ongoing research (Domanski, Kolinski, 2020; Kolinski and Werner-Lewandowska, 2021).

For the purposes of this article, a survey was carried out on a sample of 45 hospitals in Poland. The aim of the survey was to determine the digitisation readiness of hospitals in Poland.

The survey was conducted in the second half of 2021. The following research hypotheses were put forward as part of the work carried out:

- *H1: The size of hospitals determines the choice of model for drug refill.*
- *H2: The reference level of the hospital determines the degree of implementation of electronic medical orders.*
- *H3: The degree of detail of data provided by IT systems to wards/clinics determines the choice of the model for replenishment of medicines.*
- *H4: The level of detail of data provided by IT systems to pharmacies determines the choice of the drug restocking model.*

3. Literature Review

One of the therapies used in the treatment process in the hospital is pharmacotherapy, i.e., treatment with medicinal products (Palanisamy and Ranganathan, 2016). According to estimates, the average hospital in Poland manages approx. 130 thousand medicinal products (Karkowski, 2015), and drugs constitute the second - after salaries - cost-intensive element of hospital functioning (Religioni, 2016). Taking also the aspect related to the necessity to ensure an appropriate level of patient service, and mainly its safety, especially in the field of pharmacotherapy, the management of the flow of medicinal products in a hospital is an extremely important area of hospital functioning.

Inventory management is a crucial aspect of the functioning of medical facilities. Particularly important from the point of view of medications inventory management and decision-making in the selection of the most rational model of inventory management is reliable data on consumption of individual products. This data is crucial for the provision of proper medicinal products to the patient for whom they were prescribed.

Any delay in access to information or incorrect information can pose a serious threat to the health and lives of patients. It is therefore legitimate to state that patient safety is a derivative of efficiency and effectiveness, among others, of the process of inventory management of medicinal products.

Access to reliable data on the level, type and location of inventory of medicines in the hospital depends on many factors influencing the management processes of the movement of medications and patients and related information together with the actions supporting these processes in the hospital (Marasli *et al.,* 2017). Furthermore, very often the data are required in real time due to the need for the quickest possible response to the patient's needs in terms of pharmacotherapy (Gebicki *et al.,* 2014).

There are studies on how to create models of drug replenishment in the context of the warehouse space available to the hospital, as well as in the context of the current needs of the hospital (William *et al.,* 2020). In addition, many researchers have demonstrated the legitimacy of using automated tools to rationalize the replenishment process (Sara *et al.,* 2021).

There is a series of studies and studies on how to manage certain types of assortment in hospitals in the context of maintaining adequate inventory. Additionally, the results of the research are available, showing the methodology of selecting a specific model of inventory management from the point of view of the economic efficiency of hospital operation (Neve *et al.*, 2021; Sohrabi *et al.*, 2021; Farah, 2021). In the literature on the subject, however, there are no reports on research that focused on the impact of specific characteristics of a hospital on the way the hospital manages its inventory (Gawronska and Nowak, 2017).

4. Research Results

In the data presented, the use of Spearman's correlation coefficient was applied. This method consists in determining the rank that the individual results obtained in the study take in the given data. We order the data in ascending order for each of the examined variables X and Y. The smallest value of a given variable X takes the value of rank 1, and the largest has such a rank as the size of the tested group (n in this case is 45). If there are equal values of variables, we determine their rank equal to the arithmetic mean of numbers of positions, which these data occupy in the detailed series.

Spearman correlation coefficient should be determined from the formula:

$$r_s = 1 - \frac{6 \cdot \sum_{i=1}^{n} d_i^2}{n(n^2 - 1)}$$

where:
r_s – Spearman correlation coefficient,
d_i^2 – difference square of the difference between the X and Y ranks for the observation data,
n – number of observations.

Interpretation of the Spearman correlation coefficient obtained the strength of the correlation for r:

When $r < 0.2$ - no linear relationship,
When $0.2 < r < 0.4$ - weak correlation,
When $0.4 < r < 0.7$ - moderate relationship,
When $0.7< r < 0.9$ - quite strong relationship,
When $r > 0.9$ - very strong relationship.

In order to apply Spearman's correlation, the qualitative data obtained from the research were converted into quantitative data. Values were assigned for the different analytical ranges used in hypothesis verification:

Assigned value for Hospital size (number of beds): (1) Up to 200- 2; (2) Up to 400 – 4; (3) Up to 600 – 6; (4) More than 600 – 8.

Assigned value for Hospital reference level: (1) Level I – 1; (2) Level II – 2; Level III – 3.

Assigned value for degree of implementation of electronic medical order: (1) No implementation – 0; (2) Partially implementation – 2; (3) Fully implemented – 5.

Assigned value for degree of provision of data on medicines to the ward/clinic by the IT system: (1) In terms of type of assortment and stock levels – 5; (2) In terms of type of assortment – 2; (3) No data provision – 0.

Assigned value for degree of provision of data on medicines available at the ward/clinic by the IT system to the pharmacy: (1) In terms of assortment type and stock level – 5; (2) In terms of type of assortment – 2; (3) No data provision – 0.

Assigned value for Hospital's model for drug stock replenishment: (1) Model based on information level – 2; (2) Model based on a fixed ordering cycle – 1.

Examining the Spearman correlation coefficient for:

Hypotheses H1: The size of hospitals determines the choice of medicines replenishment model.

It can be obtain a study of the correlations between the data of interest, as shown in the table 2. It is possible to obtain information indicating that the Spearman correlation factor for H1 is r_s=0,191601 ($r_s = 1 - \frac{6 \cdot 12271,5}{45 \cdot (45^2-1)}$ based on Table 2). This means that there is a lack of a linear relationship. It can be concluded that it is not possible to claim that of the survey data, the size of the hospital has an impact on how that hospital replenishes its stock.

Hypothesis H2: Hospital reference level determines the degree of implementation of electronic medical orders.

The study was based on a correlation check between the data contained in table 2. It is possible to obtain information indicating that the Spearman correlation factor for H1 is r_s=0,0154 ($r_s = 1 - \frac{6 \cdot 14946}{45 \cdot (45^2-1)}$ based on Table 2). This means that there is no linear correlation between the characteristics under examination.

Hypothesis H3: The degree of detail of the data provided by IT systems to wards/clinics determines the choice of model for replenishment of medicines.

The study was based on checking the correlation between the data presented in the table 3. It is possible to obtain information indicating that the Spearman correlation factor for H1 is r_s=0,121344 ($r_s = 1 - \frac{6 \cdot 13338}{45 \cdot (45^2 - 1)}$ based on Table 3). This means that there is no linear correlation between the characteristics under examination.

Hypothesis H4: The degree of detail of data provided by IT systems to pharmacies determines the choice of drug replenishment model.

The study was based on checking the correlation between the data presented in the table 3. It is possible to obtain information indicating that the Spearman correlation factor for H1 is r_s=0,419862 ($r_s = 1 - \frac{6 \cdot 8806{,}5}{45 \cdot (45^2 - 1)}$ based on Table 3). This means that there is a medium linear correlation between the characteristics under examination.

5. Conclusions

The verification of the hypotheses put forward at the beginning of the study showed that:

- the size of the hospital has no impact on how that hospital replenishes its stock;
- hospital reference level does not determine the degree of implementation of electronic medical orders,
- the degree of detail of the data provided by IT systems to wards / clinics does not determine the choice of model for replenishment of medicines.

However, the degree of detail of data provided by IT systems to pharmacies might to some extend determine the choice of drug replenishment model.

It can be claimed that replenishment methods has no linear correlation with characteristics such as: hospital size, hospital reference model as well as detail of data provided by IT systems to pharmacies. It means that other criteria play a role in determining the way the replenishment process is organized. One of them might include hospital IT systems. Very often, IT system providers impose a specific way on hospitals to carry out the processes related to the procurement and ordering of medicines.

Consequently, this leads to situations in which hospital staff have to adapt to a predetermined process flow, and variables such as hospital size or reference level are not taken into account. However, this requires further research and verification of other factors that affect the way drug flow is managed by medical facilities.

Table 2. *Verification for H1 and H2*

Verification for H1						Verification for H2					
Hospital size	Replenishment model	Rank of variable X	Rank of variable Y	Differences between ranks	Difference squares between ranks	Hospital reference level	Degree of implementation of electronic	Rank of variable X	Rank of variable Y	Differences between ranks	Difference squares between ranks
Variable X	Variable Y			d_i	d_i^2	Variable X	Variable Y			d_i	d_i^2
2	2	2	35	-33	1089	1	5	2	40	-38	1444
2	2	2	35	-33	1089	1	5	2	40	-38	1444
2	2	2	35	-33	1089	1	5	2	40	-38	1444
4	1	12,5	12,5	0	0	2	5	11	40	-29	841
4	1	12,5	12,5	0	0	2	5	11	40	-29	841
4	1	12,5	12,5	0	0	2	5	11	40	-29	841
4	2	12,5	35	-22,5	506,25	2	2	11	17	-6	36
4	2	12,5	35	-22,5	506,25	2	0	11	2	9	81
4	1	12,5	12,5	0	0	2	5	11	40	-29	841
4	1	12,5	12,5	0	0	2	2	11	17	-6	36
4	1	12,5	12,5	0	0	2	0	11	2	9	81
4	1	12,5	12,5	0	0	2	5	11	40	-29	841
4	2	12,5	35	-22,5	506,25	2	2	11	17	-6	36
4	2	12,5	35	-22,5	506,25	2	0	11	2	9	81
4	1	12,5	12,5	0	0	2	5	11	40	-29	841
4	1	12,5	12,5	0	0	2	2	11	17	-6	36
4	1	12,5	12,5	0	0	2	2	11	17	-6	36
4	1	12,5	12,5	0	0	2	2	11	17	-6	36
4	2	12,5	35	-22,5	506,25	3	2	32	17	15	225
4	2	12,5	35	-22,5	506,25	3	5	32	40	-8	64
4	1	12,5	12,5	0	0	3	2	32	17	15	225
6	1	30,5	12,5	18	324	3	5	32	40	-8	64
6	2	30,5	35	-4,5	20,25	3	2	32	17	15	225
6	1	30,5	12,5	18	324	3	5	32	40	-8	64
6	2	30,5	35	-4,5	20,25	3	2	32	17	15	225
6	2	30,5	35	-4,5	20,25	3	2	32	17	15	225
6	1	30,5	12,5	18	324	3	2	32	17	15	225
6	1	30,5	12,5	18	324	3	5	32	40	-8	64
6	2	30,5	35	-4,5	20,25	3	2	32	17	15	225
6	1	30,5	12,5	18	324	3	2	32	17	15	225
6	2	30,5	35	-4,5	20,25	3	2	32	17	15	225
6	2	30,5	35	-4,5	20,25	3	2	32	17	15	225
6	1	30,5	12,5	18	324	3	5	32	40	-8	64
6	1	30,5	12,5	18	324	3	2	32	17	15	225
6	2	30,5	35	-4,5	20,25	3	2	32	17	15	225
6	1	30,5	12,5	18	324	3	2	32	17	15	225
6	2	30,5	35	-4,5	20,25	3	2	32	17	15	225
6	2	30,5	35	-4,5	20,25	3	5	32	40	-8	64
6	1	30,5	12,5	18	324	3	2	32	17	15	225
8	2	42,5	35	7,5	56,25	3	2	32	17	15	225
8	1	42,5	12,5	30	900	3	2	32	17	15	225
8	2	42,5	35	7,5	56,25	3	2	32	17	15	225
8	1	42,5	12,5	30	900	3	2	32	17	15	225
8	2	42,5	35	7,5	56,25	3	2	32	17	15	225
8	1	42,5	12,5	30	900	3	2	32	17	15	225
TOTAL					12271,5	TOTAL					14946

Source: *Own research.*

Table 3. *Verification for H3 and H4*

Verification for H3						Verification for H4					
The degree of detail of the data provided by IT systems to wards/clinics	Replenishment model	Rank of variable X	Rank of variable Y	Differences between ranks	Difference squares between ranks	The degree of detail of data provided by IT systems to pharmacies	Replenishment model	Rank of variable X	Rank of variable Y	Differences between ranks	Difference squares between ranks
Variable X	Variable Y			d_i	d_i^2	Variable X	Variable Y			d_i	d_i^2
0	2	2	35	-33	1089	0	2	2	36	-34	1156
0	2	2	35	-33	1089	0	2	2	36	-34	1156
0	2	2	35	-33	1089	0	2	2	36	-34	1156
2	2	14	35	-21	441	2	1	6,5	13	-6,5	42,25
2	2	14	35	-21	441	2	1	6,5	13	-6,5	42,25
2	2	14	35	-21	441	2	1	6,5	13	-6,5	42,25
2	1	14	12,5	1,5	2,25	2	1	6,5	13	-6,5	42,25
2	2	14	35	-21	441	2	1	6,5	13	-6,5	42,25
2	1	14	12,5	1,5	2,25	2	1	6,5	13	-6,5	42,25
2	2	14	35	-21	441	5	2	27,5	36	-8,5	72,25
2	1	14	12,5	1,5	2,25	5	2	27,5	36	-8,5	72,25
2	2	14	35	-21	441	5	2	27,5	36	-8,5	72,25
2	1	14	12,5	1,5	2,25	5	1	27,5	13	14,5	210,25
2	1	14	12,5	1,5	2,25	5	1	27,5	13	14,5	210,25
2	1	14	12,5	1,5	2,25	5	1	27,5	13	14,5	210,25
2	1	14	12,5	1,5	2,25	5	2	27,5	36	-8,5	72,25
2	1	14	12,5	1,5	2,25	5	1	27,5	13	14,5	210,25
2	1	14	12,5	1,5	2,25	5	1	27,5	13	14,5	210,25
2	2	14	35	-21	441	5	1	27,5	13	14,5	210,25
2	1	14	12,5	1,5	2,25	5	1	27,5	13	14,5	210,25
2	2	14	35	-21	441	5	2	27,5	36	-8,5	72,25
2	1	14	12,5	1,5	2,25	5	1	27,5	13	14,5	210,25
2	2	14	35	-21	441	5	1	27,5	13	14,5	210,25
2	1	14	12,5	1,5	2,25	5	1	27,5	13	14,5	210,25
5	1	35	12,5	22,5	506,25	5	1	27,5	13	14,5	210,25
5	1	35	12,5	22,5	506,25	5	2	27,5	36	-8,5	72,25
5	2	35	35	0	0	5	1	27,5	13	14,5	210,25
5	1	35	12,5	22,5	506,25	5	2	27,5	36	-8,5	72,25
5	1	35	12,5	22,5	506,25	5	2	27,5	36	-8,5	72,25
5	1	35	12,5	22,5	506,25	5	2	27,5	36	-8,5	72,25
5	2	35	35	0	0	5	1	27,5	13	14,5	210,25
5	1	35	12,5	22,5	506,25	5	2	27,5	36	-8,5	72,25
5	1	35	12,5	22,5	506,25	5	2	27,5	36	-8,5	72,25
5	1	35	12,5	22,5	506,25	5	2	27,5	36	-8,5	72,25
5	2	35	35	0	0	5	1	27,5	13	14,5	210,25
5	1	35	12,5	22,5	506,25	5	2	27,5	36	-8,5	72,25
5	2	35	35	0	0	5	2	27,5	36	-8,5	72,25
5	2	35	35	0	0	5	2	27,5	36	-8,5	72,25
5	1	35	12,5	22,5	506,25	5	1	27,5	13	14,5	210,25
5	2	35	35	0	0	5	2	27,5	36	-8,5	72,25
5	2	35	35	0	0	5	1	27,5	13	14,5	210,25
5	1	35	12,5	22,5	506,25	5	2	27,5	36	-8,5	72,25
5	2	35	35	0	0	5	1	27,5	13	14,5	210,25
5	2	35	35	0	0	5	2	27,5	36	-8,5	72,25
5	1	35	12,5	22,5	506,25	5	1	27,5	13	14,5	210,25
TOTAL					13338	TOTAL					8806.5

Source: *Own research.*

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