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Influence of demographic change on the blood services in Poland — logistics as a remedy for the future

Wpływ zmian demograficznych na służbę krwi w Polsce — logistyka jako remedium na przyszłość

Demographic changes linked to an ageing population make it necessary to look for ways to prevent their effects in the blood service. One forward-looking tool is logistics, offering a range of solutions, both strategic and operational in nature. The article examines the usefulness of logistics in the Polish blood services.

Key words:
demographic change, ageing, logistics, blood services.

Zachodzące zmiany demograficzne związane ze starzeniem się społeczeństwa powodują konieczność poszukiwania sposobów zapobiegania ich skutkom w służbie krwi. Jednym z perspektywicznych narzędzi jest logistyka, oferująca szereg rozwiązań, mających charakter zarówno strategiczny jak i operacyjny. W artykule rozpatrywana jest użyteczność logistyki w polskiej służbie krwi.

Słowa kluczowe:
zmiany demograficzne, starzenie się społeczeństwa, logistyka, służba krwi.

Introduction

All over the World the number of donors is an essential element "powering" the blood services. Demographic changes, emigration of young people, contemporary pace of life and factors affecting the health of the population limit the number of potential blood donors in Poland, which, with the simultaneous development of medicine, the growing number of treatments and therapies requiring its use, poses a risk of insufficient blood supply (NIK, 2015).

In the article, the blood supply is discussed in the context of demographic changes that involve a shift from younger to older age groups. Blood supply is defined as a transfer of blood from the population of donors to the population of recipients, and these two groups differ considerably in their demographic

structure. While the donor population consists primarily of young and healthy people, most patients requiring blood transfusion belong to the age groups above 60 years. This difference of age distribution between the two groups means that demographic trends are important for future blood supply (Greinacher, Fendrich, Hoffmann, 2010). The demographic change causes a double effect: reduction of the eligible donor population with a concomitant increase of patients requiring blood transfusions (Greinacher, Fendrich, Alpen et al., 2007).

This paper highlights the identification the future situation of blood services in Poland base on expected ongoing demographic changes. The authors focus on logistics as a remedy for the equalization of supply and demand for blood and its components, being aware of the use of other solutions in parallel, such as marketing activities, educational etc.

Poland in the face of demographic changes

Like other European countries, Poland's population is aging, and the implications of this demographic change need to be analyzed and understood from the perspective of blood supply and demand. According to the Central Statistical Office (Population projection 2014–2050), demographic vision of the country — that emerges from the projection — is not a surprise. We are facing a further, gradual loss of population and significant structural changes by age. Both these facts result from the known mechanisms of connections between the intensity of births and deaths, and the total population.

In the forecast period, the share of working-age population in the general population will decrease from 64% to 49%. At the same time, the post-working age population will account for 36.5% of the total population (if you consider raising the retirement age — it will increase less — to 29%). In 2014, it was 14.7%. In addition to the adverse changes in the number and structure of the population divided into economic age groups, the Central Statistical Office (GUS) draws attention to the acceleration of the pace of the double aging process. Double aging of the population means a rapid increase in the number and share of the oldest (aged 80 and over) in the population aged over 65 (double ageing). By 2025, the share of the "younger" subpopulation 65–79 will increase, because this group of older people will be gradually fed into people born in 1949–1965, while at the same time people aged 80 and more born in 1934–1945 will gradually die. After 2025, the percentage of eighty-year-olds and older will drastically increase due to the fact that this age — in subsequent years — will reach people born in 1945 and later, thus "coming" from the post-war birth boom, and the echo of this high-pressure group will feed a group of people at the age of 65 and more.

Given this information and general population health trends, this strongly suggests that the actual pool of donors with high probability will shrink in the future, at the same time — the number of potential users of blood components will almost certainly grow.

Demography and the balance of blood resources in Poland

In Poland, the blood donor may be a person aged between 18 and 65 years. In exceptional cases, the donor of blood may become a person between 17 and 18 years of age and who is 65 years old. For the purpose of this paper the following blood donors age groups are considered:

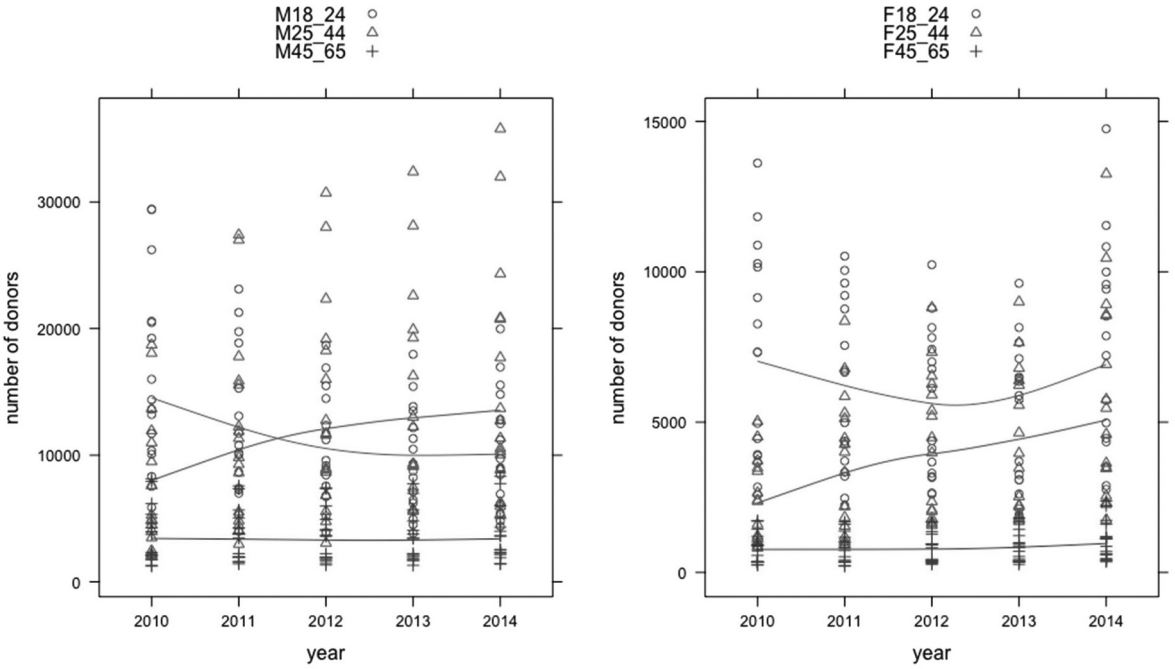
1) the population of individuals between the ages of 18 and 24 (defined as the "school aged" population);
2) the population of individuals aged 25 to 54 (characterized as "working age donors", who may have less time to donate, and therefore would have lower donor turnout rates);
3) the pre-retirement cohort includes those aged 55 to 65 are considered as "senior donors", and
4) the population over the age 65.

Complete data provided by National Blood Centre (Warsaw, Poland) cover number of blood donations by number of blood donors (separately for male and female) in four age groups (18–24, 25–44, 45–65, above 65) for time period 2010–2014 for all provinces in Poland. Thus, the database is so-called panel data — observations obtained over multiple time periods for the same provinces.

The analysis of the population structure of blood donors is particularly important, since the demographic changes will lead to an increase in absolute numbers of older patients. Trends in burden diseases (GBD, 2017; healthdata.org) indicate that there will be the disproportionate increase of patients with malignancies and other chronic diseases. Many antineoplastic chemotherapy protocols and major surgical interventions depend on sufficient blood supply.

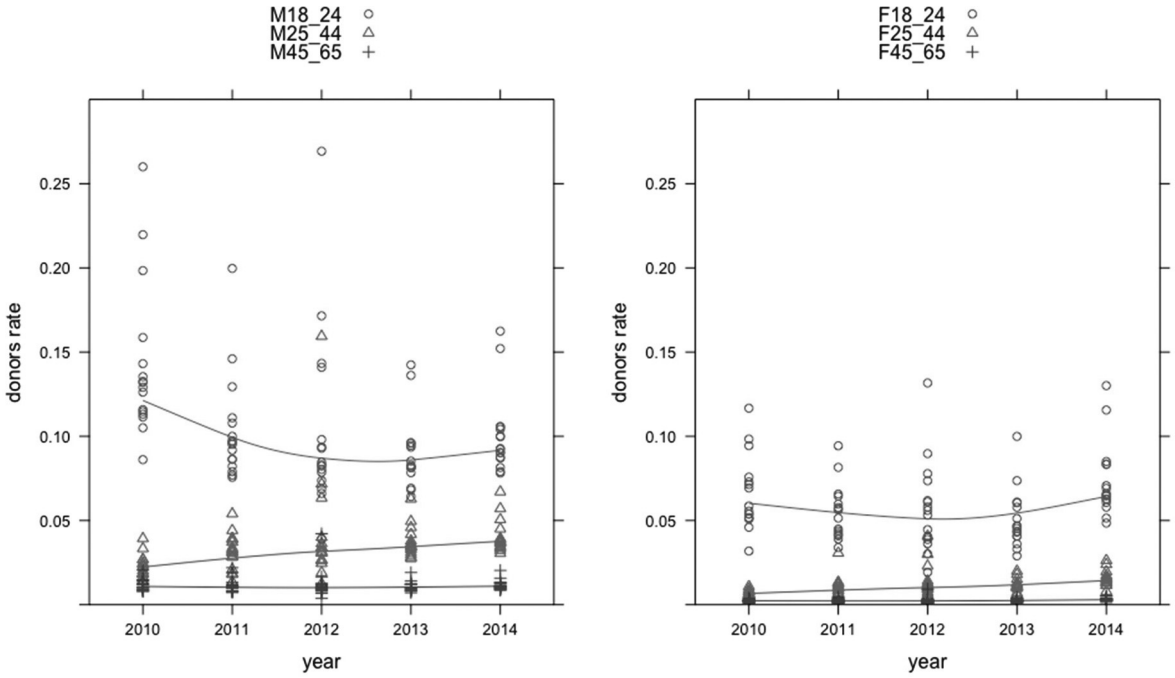
In Poland differences in age among blood donors are significant. Figure 1 presents changes in number of donors. Numbers of working age donors (female and male) increased in the time period 2010–2014. The declining trend in the number of male school

Figure 1
Number of donors according to age group and sex in 2010–2014 (Male on the left, Female on the right) for 16 provinces in Poland



Source: National Blood Centre (blood donations data) and Central Statistical Office (population data).

Figure 2
Donors rate according to age group and sex in 2010–2014 (Male on the left, Female on the right) for 16 provinces in Poland



Source: National Blood Centre (blood donations data) and Central Statistical Office (population data).

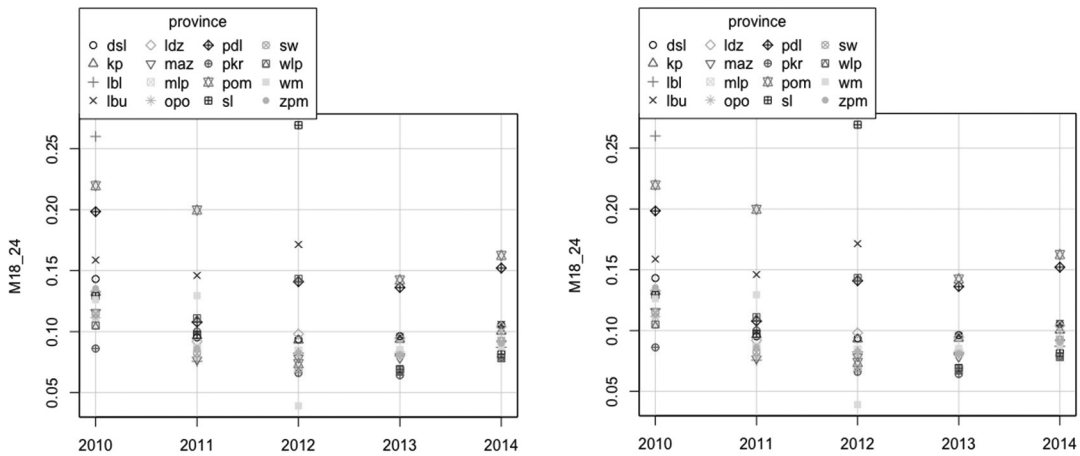
age donors is worrying. In the context of changing age structure of population the more interesting is the analysis of the donor rate defined as a number of donors in specific age divided by a number of people in the same age (figure 2). Such an analysis indicates a tendency to give blood by people aged 18–24, 25–44 and 45–65. Female dominate only age group 18–24 donors. In this group, for male and female, the decreasing trend is evident — the proportion of male donors of 18 to 24 years decreased on average from 60% in 2010 to 37% in 2014, and for female — from 72% in 2010 to 53% in 2014. Group of donors of 25–44 years increased in this period reaching on average 51% for male and 39% for female. The groups of donors' aged 45–65 were stable (12% for male and 7% for female). The proportion of donors above 65 years of age in a whole group of donors was insignificant, thus was omitted on this figure.

To sum up, the group of school age donors (18–24) is the most-active subpopulation in blood donation.

Donations per 1000 population (donation rate) vary across regions of Poland (16 provinces). The range of variation in donation rate seems to expand (in 2010 the difference between the lowest and the highest donation rate was 5.3%, while in 2014 — 7.2%). However, the average donor rate did not significantly change over time (fig. 4).

Figure 3

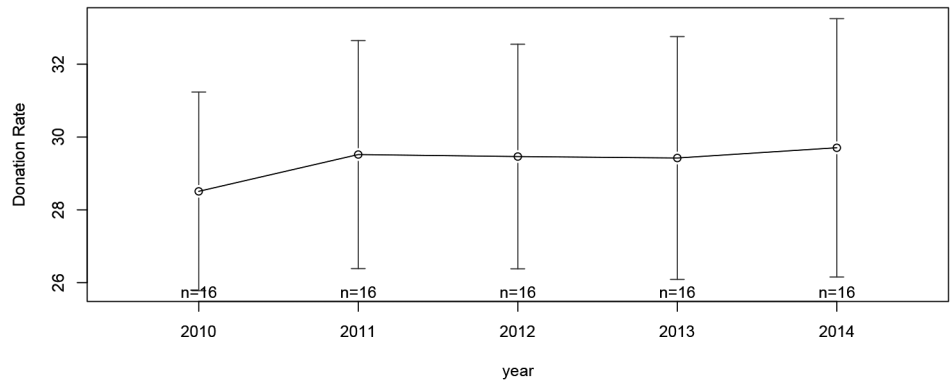
Donor rates among school age people according to sex in 2010–2014 (Male on the left, Female on the right) for 16 provinces in Poland



Source: National Blood Centre (blood donations data) and Central Statistical Office (population).

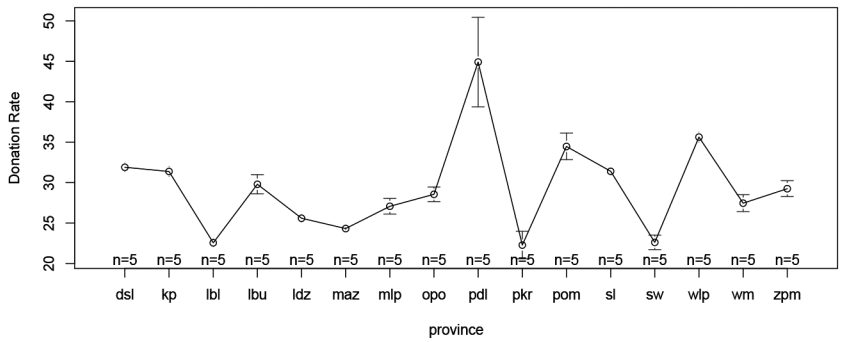
Figure 4

Donor rate across years 2010–2014 for 16 provinces



Source: National Blood Centre (blood donations data) and Central Statistical Office (population).

Figure 5
Donor rate across 16 provinces and 5 years (2010–2014)[1]



Source: National Blood Centre (blood donations data) and Central Statistical Office (population).

In most of provinces the donation rate did not change within 5 years, except of podlaskie (pdl) province (fig. 5), where the donation rate has been the highest for years. However, the heterogeneity of donor rate across provinces is observed. This heterogeneity suggests to use panel data regression models instead OLS regression in order to explain changes in donor rates.

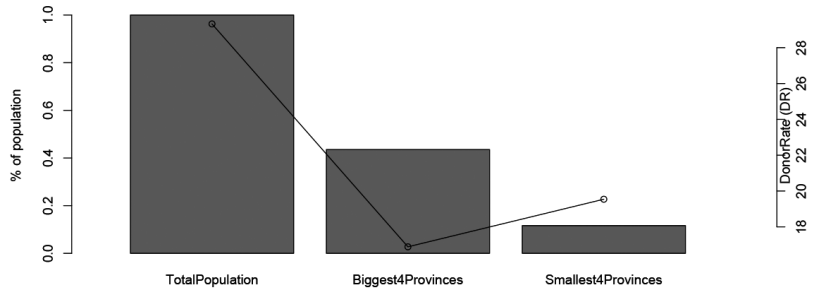
It is worth to note that slightly above 40% of the population lives in 4 provinces with the largest population (>300000 people, provinces malopolskie (mlp), mazowieckie (maz), slaskie (sl), wielkopolskie (wlp)) and about 10% in the 4 provinces with the smallest population (<130000 people, provinces lubuskie (lbu), opolskie (opo), podlaskie (pdl), swietokrzyskie (sw)). The largest provinces in the country tend to have substantially lower donor rates (fig. 6).

Past donation patterns are used to build a model for the blood supply. The model allows us to understand how changing structure population (shifting from younger to older age groups) may determine future blood demand and supply in Poland. Thus, the form of the model is simplified limiting only variables that describe the proportion of donors of specific age group in population of people of this age[2]. Table 1 introduces basic statistics for these variables. Panel data (time-series cross-section data) characterize the 16 Polish provinces between the years 2010 and 2014.

Donor rate is taken as the dependent variable to estimate the coefficients of the following a multiple linear regression model for provinces i = 1,…,16 which are observed at time periods t = 1,…5. Relevant tests provided information (see the results below the table 1) that the individual-specific (in our case provinces) effects are significant. The model has a form:

$$y_{it} = \alpha_i + x'_{it}\,\beta + u_{it}$$

Figure 6
Donor rates by geographical context (the bars present population size and the curve — donor rate in 2014)



Source: National Blood Center (blood donation data) and Central Statistical Office (population data).

Table 1
Variables with definitions and descriptive statistics panel data

Variables	Definition and units	Min	Max	Mean	SD
Dependent variable:					
DONATION	Donation rate per 1000	20.37	50.28	29.32	5.82
Independent variables:					
Donors_18–24*	The share of populationof 18–24 years of age in population at this age (per 1000)	0.026	0.232	0.096	0.022
Donors_25–44*	The share of populationof 25–44 years of age in population at this age (per 1000)	0.081	0.744	0.310	0.070
Donors_45–65*	The share of populationof 45–65 years of age in population at this age (per 1000)	0.077	0.636	0.278	0.063
Donors_65+*	The share of population over the age of 65 years of age in population at this age (per 1000)	0.000	1.620	0.069	0.201
Province Name**	Province-specific dummy variable				

*Hollingsworth and Wildman (2004) and Burnett (1982) indicate that donation rates vary in relation to the number of individuals present for different age groups
** Provinces are introduced to account for fixed (province-specific) effects in the form of dummy variables. The objective of these dummy variables is to capture any contextual variation specific to provinces that is not attributable to other explicative factors.
Source: own elaboration.

Table 2
One-way (individual) effect Within Model

Variable	Estimate	Std. Error	t-value	Pr(>|t|)
Donors_18–24	0.08782	0.03351	2.6202	0.01074 *
Donors_25–44	0.30464	0.15097	2.0175	0.04742 *
Donors_45–65	–0.92163	0.66211	–1.3920	0.16828
Donors_65+	1.369204	3.25334	0.4209	0.67513
dsl	31.98365	0.82208	38.906	<2.2e–16***
kp	31.67461	0.82700	38.300	<2.2e–16***
lbl	22.41817	0.81983	27.345	<2.2e–16***
lbu	29.88853	0.86021	34.746	<2.2e–16***
ldz	25.63395	0.80313	31.918	<2.2e–16***
maz	24.48599	0.75911	32.256	<2.2e–16***
mlp	27.19286	0.75582	35.978	<2.2e–16***
opo	28.84385	0.89238	32.322	<2.2e–16***
pdl	44.71058	1.01022	44.258	<2.2e–16***
pkr	22.38582	0.68993	32.447	<2.2e–16***
pom	34.81755	0.98771	35.251	<2.2e–16***
sl	31.36489	0.95747	32.758	<2.2e–16***
sw	22.86131	0.74069	30.865	<2.2e–16***
wlp	35.39687	0.80327	44.066	<2.2e–16***
wm	27.48202	0.73916	37.180	<2.2e–16***
zpm	29.00827	0.76823	37.760	<2.2e–16***

Balanced Panel: n=16, T=5, N=80.
Lagrange Multiplier Test — time effects (Honda) (Testing time-fixed effects): p-value = 0.8728.
Lagrange Multiplier Test — individual effects (Breusch-Pagan) (Testing individual-fixed effects): p-value < 2.2e–16
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '*' 0.1.
R-Squared: 0.36029; F-statistic: 7.2781 on 4 and 71 DF, p-value: 5.7059e-05.

Source: own elaboration.

where y_{it} is the dependent variable, x'_{it} is a k-dimensional row vector of time-varying explanatory variables, α_i are individual intercepts, β is a k-dimensional column vector of parameters, and u_{it} is an idiosyncratic error term. α_i is empirically modeled by estimating unit-specific dummy variables (so-called LSDV model — least squares dummy variable model) which gives rise to province-specific intercepts.

With two exceptions, the coefficients are significant at the level $p < 0.05$ (table 2). Individual (provinces) effects are significant. The proportion of people aged 18–24 and 25–44 correlates positively with donation rate, whereas people aged 45–65 correlates negatively but insignificantly. When the proportions of donors aged 18–24 and 25–44 increased by 1%, the donation rate increased on average by 0.08% and 0.30% respectively.

The fit of the model is not high, with the model explaining about 36% of the variance (according to R-square), all of province-specific dummy variables (16 candidates) indicate that there tend to be significant and substantial contextual effects.

The model indicates that the key groups of donors across all provinces and years are school age and working-age people. Such patterns of donors ensure stabilization and self-sufficiency of the country in terms of blood and its components supply.

The presented situation, despite of its limitations, has a relatively large forecast value of outlining the situation of blood and blood components balance in the country. Assumptions in the context of creating the system of blood supply in Poland in 2050 are as follows:

1) demand for blood is growing; there is a significant increase in demand for blood in the age group of 65+;
2) potential progress in medicine resulted in blood demand has not been taken into consideration:
   a) potential decrease in demand for blood and possible replacement with artificial blood;
   b) potential decrease in blood transfusion cases resulting from prophylactics;
3) Polish self-sufficiency in the context of blood availability is guaranteed;
4) no significant changes in the system of blood services.

Meeting the requirement of the availability of the optimal amount of blood and blood components taking into account medical requirements (blood alignment by group and term) to the needs of patients undergoing treatment with blood and blood components can be solved using logistics, which has an extensive set of tools to achieve availability depending on different configurations of the existing conditions.

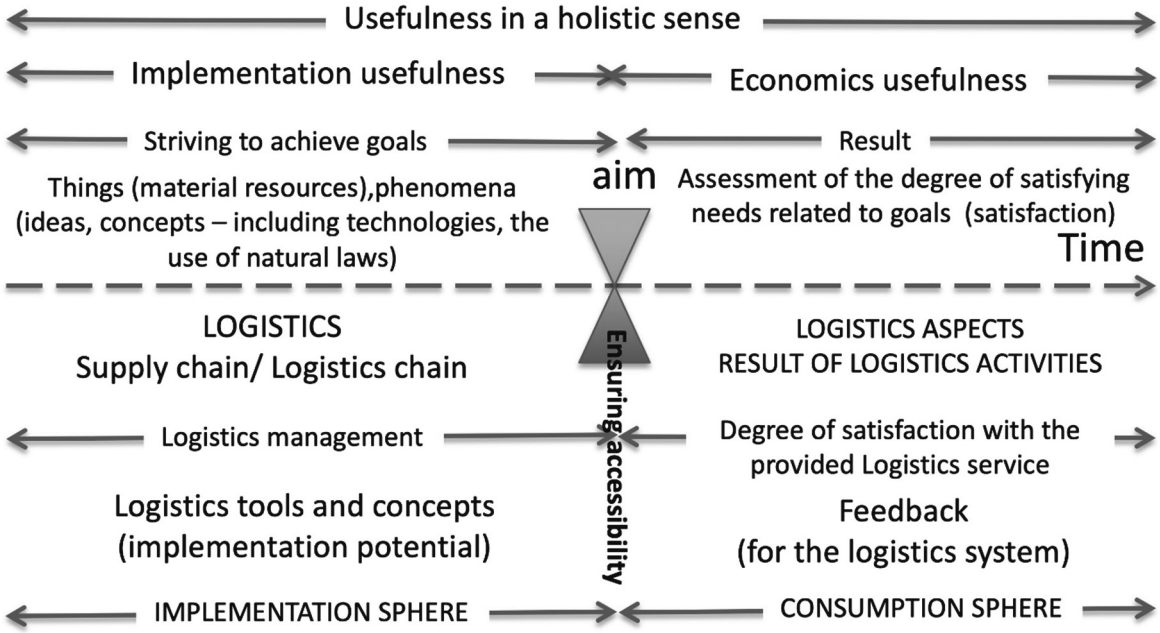
Logistics' usefulness in the functioning of the blood services system

Logistics is a field of practical knowledge, which means that in addition to theoretical reflection, it offers practical tools. "Logistics is shaping (using logistics management) of material and information flows in order to achieve accessibility (to material goods or places) on established principles and priorities for actions" (Szołtysek, 2015). The essence of logistics is to configure resources in such a way that flows shaped by logisticians (material, informative) lead to the maximum usefulness resulting from the availability of products (or the possibility of reaching places) on the agreed terms (figure 7). Thus, part of economic utility, understood as the degree of satisfaction (pleasure, benefit, satisfaction, etc.), which is related to the circumstances resulting from accessibility, is implemented by means of logistics actions. However, logistics creates this conditions earlier, as part of the logistics management process in the realm of implementation. Hence, the assessment of the usefulness of logistics (understood as the assessment of the skilful use of things and phenomena) within the framework of logistics management, can and should be considered on the basis of implementation utility (Szołtysek, 2017, p. 91).

The purpose of the blood services in Poland is to ensure the availability of the appropriate group of blood or blood components, the right patient, at a place and time designated for this purpose, in the amount necessary for an effective treatment process. It is the most simply described usefulness in the "sphere of consumption", which is the result of logistics activities, and necessary to ensure a high quality of life for inhabitants of our country. This is how blood services strategies are built in Poland. These strategies can be reduced to (Twaróg, 2014): a gradual transition from the situation of greater dispersion of logistics tasks in existing supply chains (individual phases 1–5 — table 3 with possible partial consolidations, e.g. phase 2 + 4) towards a greater degree of integration — from the role of the chain leader, through chain management by a logistics operator (Płaczek, Twaróg, 2013; "phases 6"), to purpose network structures of blood supply (combined multiplied "phases 6") as a result. Therefore, at the stage of designing and implementation of the blood services in Poland (left side of Figure 7), logistical tasks should be carried out in accordance with the state of the knowledge in this area.

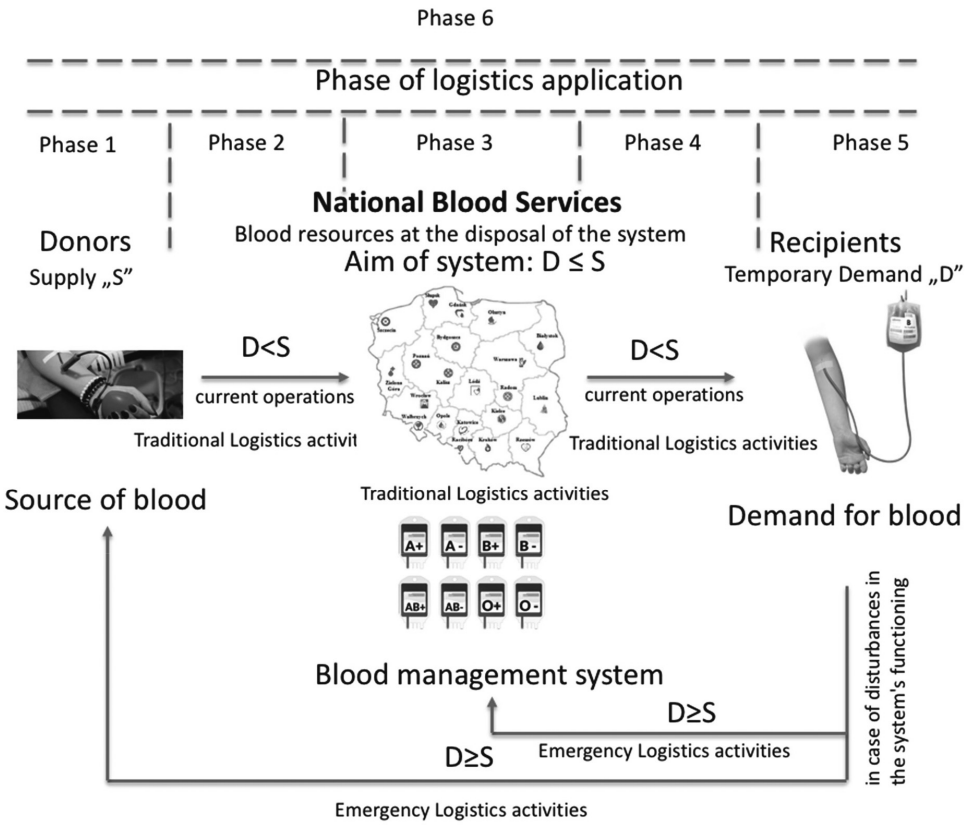
The usefulness of logistics in the National Blood Services (LNBS) is not only considered as a result

Figure 7
Usefulness and its application fields in logistics



Source: Szołtysek, 2017, p. 91.

Figure 8
Logistics in blood services — areas of competence



Source: own elaboration.

of a long-term situation in which the temporary demand for blood and blood components "D" is at least equal to the supply of "S", adjusted for stocks in the NBS. The conditions for achieving this objective require that the availability of blood resources should be carried out according to time-space principles as well as quality and medical principles. The main benefits of the use of logistics should be seen in the sphere of implementation, i.e. mainly in phases 1–6 (Figure 8), implemented using so called "traditional" L_T logistics (ie traditional methods and tools, identified with business logistics) with the reservation that management decisions are made to a predominant extent according to the concept of L_S social logistics, and in established cases in the area of L_G business logistics. In Figure 7, apart from "traditional" logistics, we deal with "emergency" logistics (L_E) — corrective and corrective actions, removing the effects (or anticipating their occurrence) of implementation disruptions that lead to the risk of a lack of blood availability.

Referring these considerations to the demographic forecast and the potential situation of the blood services it can be assumed that the significance of "emergency" logistics will be much greater, but nonetheless largely dependent on "traditional" logistics. Hence:

Logistics of a National Blood Services L_{NBS}:

- Is a sum of "traditional" logistics L_T and "emergency" logistics L_E;
- where L_E should decrease its share and L_T increase its participation:
- $L_T + L_E = 1$;
- L_R reverse logistics is mainly included in L_T;L_{NBS} $(L_S + L_G)$ where L_G is limited to designated areas.

The usefulness of logistics is therefore closely related to its effectiveness, also determined by ensuring a properly functioning blood services, enabling an efficient and adapted to current needs to supply patients with blood and its components, ensuring their appropriate quality and optimal use.

The most predestined solutions offered by the theory of logistics, including social logistics, related to demographic change, which can be successfully applied, include: selection of the place, frequency and moments of collections of blood and blood components (for phase 1), reorganization of the structure of the blood services, creation of a new organizational culture, oriented towards on cooperation and innovation (regarding phase 6) — table 3.

Conclusions

The main cause of uncertainty of the blood services are demographic mechanism — independent of the national blood services, according to which in Poland, as in most European countries, the life expectance rate increases, the group of potential donors decreases, so in the blood services they may — and most likely will occur — problems with obtaining blood to the system (disturbances at entering the system). One of the ways to reduce these disturbances is the extensive and comprehensive use of logistics, which is a specific mixture of LT and LE and incorporated in these LR applications. In the article, the authors point out that logistics can have a range of applications — from specialized local (within one phase), to a larger scope (connecting different phases in joint management), ending with comprehensive logistics management. Logistic activities can be divided in this area into tasks implemented as part of logistics projects in a strategic and operational perspective. While in the executive area, the logistics specialists are composing various effective solutions [Twaróg, Szołtysek 2018] allowing to: optimize the size and type of stocks, their distribution in the chain structure, selection of methods and determination of the right pace of movement, in the management system logistics suggests, among other things of configuring supply chains and supply networks, as well as principles of locating "power" in these structures.

The authors agree that the conclusions of the presented study may be useful in the following areas:

1) institutions that are involved in functioning of the blood services in Poland, including those, that are responsible for national health safety;
2) all other institutions that create programs that encourage people to donate blood (PR agencies, non-government organizations, etc.) and
3) educational system entities (kindergartens, schools, universities).

In all these areas there is a real possibility of using logistics to try to actively change the situation of blood services in Poland.

Table 3
Proposals for action in the field of searching for the suitability of logistics

Phase	Directions of management decisions in the field of logistics	The nature of decisions	The leading tool	Expected effect
Phase 1	Selection of the place of the mobile session — location of the blood collection point	operational	Lean/Agile	Health security
	Choosing the frequency of the organization of mobile sessions	operational		Availability/
	Defining the method of organization of blood collection	operational		/Usability
Phase 2	Selection of the way of carrying blood	operational		of time
	Selection of frequency of transportation	operational		and place
	Choosing the optimal route	operational		
	Selection of transport packaging considering storage conditions	operational		
Phase 3	Determining the moments of collection	operational		
	Determining the demand for storage space	operational		
	Determining the number of ambulances/outgoing teams	operational		
	Optimization of the size and type of stocks	operational		
	Choice of the method and determination of the flow rate in the system	operational		
	Implementation of logistics innovations	strategic		
Phase 4	Selection of the way of carrying blood	operational		
	Selection of transport frequency	operational		
	Choosing the optimal route	operational		
	Selection of transport packaging considering storage conditions	operational		
Phase 5	Centralization vs. decentralization of hospital blood banks	strategic		
	Selection of size and type of stock in hospital blood banks	operational		
Phase 6	Choosing an authority location/logistics network leader in the system (focal company/logistics provider)	strategic		
	Configuration of the logistics network in the system with the coordinator at the forefront	strategic		
	Implementation of logistics innovations	operational/ /strategic		
	Group purchase	strategic		
	Choosing a mix of push-pull strategies	strategic		

Source: own elaboration.

[1] Names of the provinces: dsl dolnoslaskie, kp kujawsko-pomorskie, lbl lubelskie, lbu lubuskie, ldz lodzkie, mls małopolskie, maz mazowieckie, opo opolskie, pkr podkarpackie, pdl podlaskie, pom pomorskie, sl slaskie, sw swietokrzyskie, wm warmińsko-mazurskie, wlp wielkopolskie, zpm zachodnio-pomorskie.

[2] The authors are aware of the fact that the increase of blood supply and demand cannot be explained solely by changes in populations in a particular age group. On the one hand, many different variables describing population can be considered, e.g. unemployment, income, education. On the second hand, some external factors can be taken into account. For example, Patient Blood Management Program, medical progress may reduce a blood demand. Unlike the demographic changes, the consequences of medical progress on future blood demands cannot be modeled reliably.

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