Developing an Algorithm for the Management of Local Government Expenditures

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Abstract

The research objective is to is to develop an algorithm to computerise the process of allocating the limited resources of a local government to maximise the needs of the community. With limited financial resources, local governments must determine the optimum volume of planned services to be provided. The increasing amount of information, as well as the need for rapid management decision-making, necessitates the use of information and computer technologies (ICT) in this area.

Research methods used: comparative analysis, planning theory, utility analysis, design of software module, analytical methods.

Results of the research: The paper contributes to the theoretical studies about ICT implementation in local governance. Also, the paper contributes to the discussion of the practical implementation of ICT in the allocation of limited resources at the local governance level.

Keywords

Algorithm, utility, software, management, expenditure optimisation

1. Introduction

The management of any socio-economic system involves the process of collecting and processing large amounts of data. Moreover, in today's changing economy, management involves rapid decision-making in the face of not only economic and political stresses, but also, as evidenced by the events of 2020-2021, a global health system crisis [10; 23].

The key component needed for making sound management decisions at the community government level is information about the population's need for various public services. Local governments must understand what interests are shared by their communities [2; 11]. Those planning local government activities must consider needs and interests of their constituencies. At the core of any community's social and economic model must be quality of life. This refers to life expectancy, the provision of quality food, accessibility to quality education, provision of utilities, business opportunities, recreational opportunities, and the like. Consequently, the performance of the local government can be deemed effective if the local government provides the conditions for improving the general quality of life of the community members.

Effective governance occurs when limited resources are allocated with the maximum benefit to service beneficiaries. However, it must be admitted that this principle is not always applied by local governments, as the responsibilities of local governments have different areas of focus. Priority is given to the regulation of property issues [8], construction works [9], environmental protection [3; 17; 19], and, in the case of border regions, the priority is also given to cross-border cooperation [12].

To maximise outcomes for service beneficiaries in a resource-constrained environment, information on the actual needs of the population needs to be kept up to date. This enables the allocation of resources to be planned to maximise the satisfaction of the community. It should be noted that utility for each

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individual beneficiary is relative and is primarily aimed at satisfying priority needs. With the diversity of these objectives, it is quite difficult to distinguish what requires the attention of local authorities first: provision of housing, creation of jobs, level of healthcare, provision of quality utilities (water supply, sanitation, electricity), environmental protection, etc. In addition, each service, as it becomes available, has a greater or lesser weight in the whole set of services.

With limited financial resources, local governments must determine the optimum volume of planned services to be provided. This requires the identification of an optimality criterion and the constraints on the resources that are necessary to carry out the functions specified. Also, the decision-making process of resource allocation requires proper accountability to prevent corruption.

The increasing volume of information, as well as the need for rapid management decision-making, necessitates the use of information and computer technology (ICT) in this area. First, special software for the limited resources allocation must be developed. However, this software must not be rigidly configured. It should contain a flexible algorithm that allows adaptation not only to the needs of the region, but also to new external stressors. Second, the special ICT module must be developed to control the risk of misused funds. The aim of the article is to develop an algorithm to computerise the process of allocating the limited resources of the local authority to maximise the needs of the community.

The paper contributes to the theoretical studies about ICT implementation in local governance. Also, the paper contributes to the discussion of the practical implementation of ICT in the allocation of limited resources at local governance level.

The paper is organized as follows: the second section describes related literature. It is divided in two subsections; the first subsection summarizes the results of recent studies about fund redistribution at the local level, and the second part summarizes current ideas regarding ICT usage for local governance improvement. The third section describes methodology; the fourth section is devoted to the discussion of the research results; and the final part of the paper contains conclusions and prospects for further research.

2. Literature Review

2.1. Local Government Decision Making Regarding Funds Redistribution

The problem of optimising the expenditures made by local governments, together with improvements in efficiency, is one of the most debated issues among economists [14; 15; 18; 36]. The main research topics concern the impact of local government spending redistribution on regional development. Funding allocation decisions have short-term and long-term effects. A positive short-term effect does not always mean a positive dynamic in the long term. However, politicians often favour decisions whose positive outcome is visible in the short term in order to enhance their chances for re-election. Therefore, we believe that an improved process of redistributive funding at the local level, together with stable fiscal policy, should enable politicians to form sounder distributive decisions benefiting the community.

De Vries MS (2000), Saltman R. et.al. (2006) studied how decentralization can influence the efficiency of local governments and allocation of limited financial resources [21; 42]. Scholars have pointed out that for some countries decentralization can be a challenge. Decentralization itself does not provide a guarantee for higher efficiency in limited funds allocation. Decentralisation in developing countries may further exacerbate redistribution problems due to high levels of regional economic inequality. Within this situation, there is a very high risk that political decisions on the allocation of funding will further deepen inequalities.

Shusheng Wu, et. al. (2017) explore the influences of government expenditures and corruption on total factor productivity. Increasing the proportions of government expenditures could improve the total factor productivity up until a threshold value [44]. Scholars point out that increased corruption in the allocation of resources locally is likely to reduce productivity and economic development. Funding allocation will always be associated with high risks of corruption, so the reallocation process should be as transparent as possible and prevent "manual" distribution of funds.

Adewuyi, A. (2016), Halkos, G. E., Paizanos, E. A., (2013.) studied direct and direct government expenditures on environmental pollution. One of the findings shows that the effect depends on the

income level of a country [1; 26]. It should be noted that it is exceedingly difficult to study the relationship between the income level of a region and the optimal allocation of financial resources, as there is a pronounced causal effect between these two factors.

Many scholars stressed that expenditure distribution has the capacity to support economic growth, but at the same time expenditure management has a high risk of corruption growth [4; 6]. In other words, the allocation procedure for finite financial resources should be distributed by local governments in a way that minimises the risk of corruption and maximises economic development.

Several key aspects should be highlighted that need to be explored in greater depth. First among these is what criteria are needed to be considered when allocating funding at the local level. Second, whether such criteria can be the same for developed and developing countries needs to be determined. Third is an examination of whether the allocation process can be automated to reduce the influence of the human factor on the allocation process.

2.2. Computer Technology in the Local Governance Redistribution Process

The evolution of e-governance at the local level was studied by García-Sánchez, I. M. et.al. (2013). The authors proved that Spanish municipalities display high information transparency in economic, environmental, and social matters, allowing the undertaking of administrative proceedings online and actively promoting the participation of interest groups in strategic, sustainable, and managerial issues [25]. At the same time, they pointed out changes in legislation are needed to develop the collaborative relationship between government and society.

Hanzl, M. (2007) looked at informational technology in local governance as a tool for increasing local government efficiency and accountability [27]. Pereira, V., et.al. (2017) proved that the implementation of ICT in governance can improve citizen collaboration with local government [39]. A special feature of local government is its direct proximity to the citizens. In other words, the link between the taxes paid and the public services received is stronger here. Therefore, accountability requirements for local governments are much higher and more complex than for the central government. Moreover, e-governance at the local level should develop towards ensuring high accountability of local governments, especially in terms of decision-making regarding the allocation of funding and the efficiency of its utilisation.

Pfeffer, K. et. al. (2011) proved that using GIS throughout the process of local governance provides an understanding of the local context, enriches knowledge obtained from local databases, and therefore supports multiple forms of knowledge acquisition [40].

A large number of papers are devoted to studies on how different ICT tools can be used in governance to balance the interests of government and citizens. Al-Mushayt, O. S. (2019), Aoki, N. (2020). Bullock, J. B. (2019) studied how artificial intelligence can be used in e-governance. Researchers argued that discretion and decision-making are strongly influenced by intelligence, and that improvements in intelligence, such as those that can be found within the field of artificial intelligence, can help improve the overall quality of administration [5; 7; 13].

Desouza, K. et. al. (2020) studied the best practices of artificial intelligence in e-governance implementation and developed ideas for capturing value with cognitive computing systems [20]. Janssen, M. et.al. (2020) investigated how to improve the management of large data sets to ensure high efficiency in public administration and prevent possible disruptions [29].

Kuziemski, M., & Misuraca, G. (2020) have considered the ethical dimension of ICT implementation in the public sector. The authors point out that many governments have a dilemma to resolve. On the one hand, governments are increasing their use of information technology in order to improve their own efficiency. On the other hand, governments need to protect citizens from the unauthorised retention of their personal information [30].

Lynch, N. A. (1996), Lynn, L. E., et.al. (2000) contributed to the study of distributed algorithms and their applications in public e-governance [31; 32]. Mikhaylov et.al. (2018) discuss the opportunities for artificial intelligence in the public sector. Also, they identified challenges of artificial intelligence for providing public services. They propose a series of strategies to successfully manage these cross-sectoral collaborations [33].

In our previous studies, we have explored how the use of geographic information systems can improve the effectiveness of health and education reforms at the local level [37], how the use of information systems in deliverology can improve the effectiveness of local government funds and improve the quality of public services provided [14; 15], and how the use of information systems affects the effectiveness of government [38]. We have conducted our research using both a sample of European countries and local governments in Ukraine and found that ICT can contribute to better governance. The key condition for success is to consider the features of a particular region. For example, in some regions the accountability of a local government could be the key issue. Therefore, the development of e-governance must tackle this issue with determined attention. Other regions could possibly have higher transaction costs at the decision-making stage of fund redistribution. Therefore, distribution decisions must be formalized as much as possible and human intervention must be limited unless fiscal policy has been changed radically.

3. Research Methodology

The first methodological issue to be addressed for our study is the choice of the criteria for optimal allocation of funding. Unlike most organisations, a local government cannot use profit as the main criterion for optimising its performance, as its main purpose is to create the conditions to ensure the provision of services that are most beneficial to citizens. Planning the provision of services is complicated by the fact that the utility of the same service for a citizen will diminish as demand is met.

The current literature uses different methodological approaches to address this issue, but the key aspect is the impact of distribution on the well-being of citizens. Piacenza, M. & Turati, G. (2014) studied how fiscal discipline at local level affects the wellbeing of a community. They separate efficient healthcare spending from inefficiencies by estimating an input requirement frontier [41]. Ferrario C, Zanardi A. (2011) pointed out that mistakes in the determination of proper criteria of redistribution optimization may lead to fiscal disbalances in funding [24]. Some regions will spend more, and other regions will spend significantly less for the same public services.

Many researchers are focused on the advantages of blockchain usage in local governance [27; 35; 43; 46]. Doumpos M. and Cohen S. (2014) used a data envelopment analysis to obtain efficiency estimates. They explored the optimal reallocation of municipality inputs and outputs to provide policy recommendations regarding fund reduction [22].

Many current studies are keen on planning theory. For example, Xiaoyong Xiao, Chao Xie (2021) take the smart city construction model as a research object and study the advantages of smart city construction and its impact on people's lives based on big data and rational planning theory [45]. Castro, V. and Martins, R. (2019) stressed that political manipulation risks must be considered during the process of budget planning [16]. Morozumi, F. et. al. (2014) pointed out the impact of electoral effects on government expenditure composition and possible criteria to be used [34].

Considering this circumstance, it is required to solve the problem of planning the provision of services to the community by the criterion of utility maximisation in the context of limited financial resources. This involves calculating the number of services corresponding to the accepted unit of money multiplied by the utility from the consumption of the service at each planning step. Following this criterion, it is necessary to satisfy such constraints that the volume of services provided should not exceed the available financial resources needed in the local government budget.

The service planning method allows local governments to determine the type of service as well as the amount of service using the available resources while achieving maximum utility. To solve the problem, input information on the change in the marginal utility of services is needed for the planning steps. Since each service has a different cost, it is crucial to calculate the marginal utility of the adopted monetary unit to make the comparison. The input information also needs to include the value of each unit of service created and the volume of services.

4. Research Results and Discussion

The planning process starts with selecting the service that has the maximum utility for the majority of citizens based on the provisions of the median voter theory. A method of expert assessments should be applied to evaluate the utility of consumption of these services, where the experts (respondents) are mainly the beneficiaries of these services themselves.

This choice can be made by asking respondents to assess the completeness and quality of services provided by local governments. The respondents in this case should be the residents of the communities concerned, as they are the beneficiaries of the public services. Based on the need for the service, the respondent assesses the utility of the unit of service on a ranking scale. Each respondent thus provides a ranking quotient for the utility of each service. The list of services and the ranks depend on the authority of the local government to provide specific services.

Another way in which information about marginal utility can be obtained is the analysis method. It is used to assess the utility of services and compares the level of service delivery provided by the local government with that of similar services in a benchmark region. For example, it could be the most successful region in the country under study or a benchmark from a comparable region in a developed country.

Once the public service with the highest utility has been selected, the value according to which the comparable marginal utility has been calculated is subtracted from the budget constraint. In the second planning step, the marginal utility of the services that have not been selected remains unchanged, while the marginal utility of the selected service changes. Similarly, selection takes place in all subsequent planning steps. The selection process is completed when the budget constraint reaches zero.

Following the selection process, it is necessary to find the best plan for service provision. At the beginning, the number of services to be planned at each step is calculated. Then the amount of services in all planning steps is calculated, which makes it possible to determine the total utility (1).

$$\left.\begin{array}{r} \sum_{i=1}^{N} U_{sc} \rightarrow max \\ N_s = const \\ SC \leq BC \end{array}\right\} \quad (1)$$

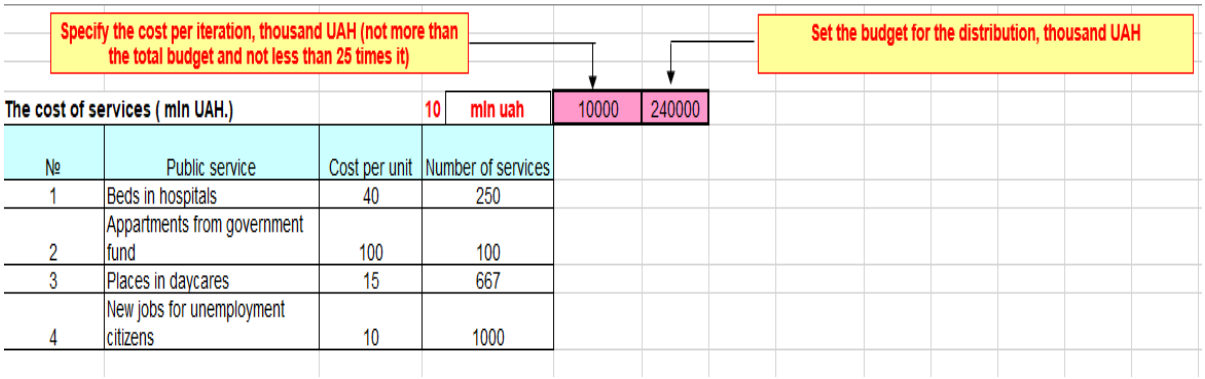
U_{sc} – total utility of public services provided;

N_s – number of public services provided. It depends on a country fiscal policy and particular local government.

SC – cost of public services.

BC – budget constraint.

The planning is done according to the utility maximisation criterion, and the constraints for the target function are satisfied. To solve the optimization problem the following algorithm was developed (Figures 1-6). The first stage of the planning is shown at the Figure 1.



№	Public service	Cost per unit	Number of services
1	Beds in hospitals	40	250
2	Appartments from government fund	100	100
3	Places in daycares	15	667
4	New jobs for unemployment citizens	10	1000

Source: designed by authors

Figure 1: The First Stage of the Budget Optimization Process

At the first stage of the local budget optimisation process is the input of initial data. The initial data is comprised of the cost of public services per iteration, the budget constraint, and the cost per unit for each public service provided by a local government.

The next stage of the planning is calculation of marginal utilities changes. In our example we calculated those changes for four types of services, but the same calculations can be made for the bigger number of services.

Change of marginal utility of services by subsequent units, Util /unit. Service

	Utility from the consumption of each additional unit of a service			
Unit of service	Hospital beds	Appartments from government fund	Places in daycare	New jobs
1	0,28	0,65	0,075	0,1
2	0,248	0,61	0,065	0,072
3	0,22	0,58	0,059	0,054
4	0,196	0,56	0,053	0,042
5	0,172	0,54	0,047	0,032
6	0,152	0,52	0,04	0,024
7	0,14	0,5	0,036	0,018
8	0,128	0,49	0,032	0,014
9	0,116	0,47	0,029	0,011
10	0,104	0,45	0,026	0,009
11	0,096	0,43	0,023	0,007
12	0,088	0,42	0,02	0,005
13	0,084	0,41	0,017	0,004
14	0,08	0,4	0,015	0,003

Source: designed by authors

Figure 2: Change in the Marginal Utility of Public Services

The results displayed in Figure 2 is calculated based on the survey or analytical procedures described at the beginning of this section. For our experiment we used the survey which was redistributed among the members of community via emails, social media, and regular post. Regular post was chosen because older people quite often do not use emails or social media. The response rate was 64.5%. We cannot reach 100% response rate, but it does not breach the principle of optimal distribution, because almost everybody has a chance to be involved in the evaluation process.

At the next stage of the algorithm the marginal utility for each additional service is calculated (Figure 3).

Marginal utility of services by subsequent units,

Util / 10 mln uah

Utility from the consumption of each additional service

Beds (A)	Apartments provided from the government	Places in the daycare (C)	New jobs(D)
250	100	667	1000
70	65	50	100
62	61	43	72
55	58	39	54
49	56	35	42
43	54	31	32
38	52	27	24
35	50	24	18
32	49	21	14
29	47	19	11
26	45	17	9
24	43	15	7
22	42	13	5
21	41	11	4
20	40	10	3

The number of services that corresponds to the value of the currency unit adopted

10 mln UAH

Source: designed by authors

Figure 3: Marginal Utility Calculation for Each Additional Unit of Service

The next stage of the algorithm is a calculation of the number of iterations (Figure 4).

Define the number of steps as the ratio of the budget constraint to the cost per iteration

=F4/E4

№ of iteration	Indicator	Utility services for the iteration A	B	C	D
1	-	70	65	50	**100**
2	-	70	65	50	**72**
3	-	**70**	65	50	54
4	-	62	**65**	50	54
5	-	**62**	61	50	54
6	-	55	**61**	50	54
7	-	55	**58**	50	54
8	-	55	**56**	50	54
9	-	**55**	54	50	54
10	-	49	54	50	**54**
11	-	49	54	**50**	42
12	-	49	**54**	43	42
13	-	49	**52**	43	42
14	-	49	**50**	43	42
15	-	**49**	49	43	42
16	-	43	**49**	43	42
17	-	43	**47**	43	42
18	-	43	**45**	43	42
19	-	**43**	43	43	42
20	-	38	43	43	**42**
21	-	38	43	**43**	32
22	-	38	43	**39**	32
23	-	38	**43**	35	32
24	Last money	38	**42**	35	32
25	-	38	**41**	35	32

Source: designed by authors

Figure 4: The Calculation of the Number of Iterations

The next stage of the algorithm consists of a number of steps which are equal to the number of iterations calculated in Figure 3. The number of iterations depends on budget constraints and utilities

30000 -

40000

50000 =IF(U86<F4;" budget surplus";IF(U86=F4;" budget constraint";"budget deficit"))

budget surplus

of services. At each step of the algorithm, the availability of funds is checked. The result of the check is displayed as a message which can be “budget surplus”, “budget constraint” or “budget deficit”. A fragment of the calculation is shown in Fig. 5.

Source: designed by authors

Figure 5: The Fragment of Calculations per Iteration

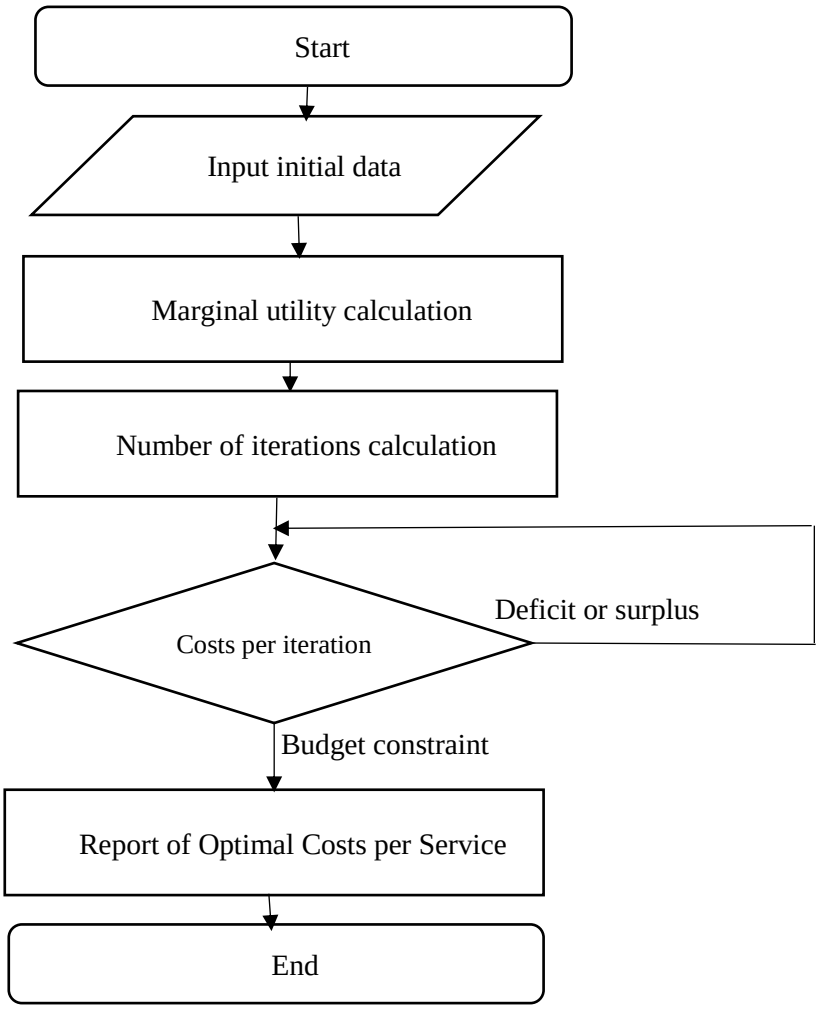
The final results of the calculations as a report are shown on the Figure 6.

Total Unility	Number of services for iteration				Costs for iteration				Total costs		Indicator
	A	B	C	D	A	B	C	D			
100	0	0	0	**1000**				10000	10000	-	budget surplus
172	0	0	0	**2000**	0	0	0	20000	20000	-	budget surplus
242	**250**	0	0	2000	10000	0	0	20000	30000	-	budget surplus
307	250	**100**	0	2000	10000	10000	0	20000	40000	-	budget surplus
369	500	100	0	2000	20000	10000	0	20000	50000	-	budget surplus
430	500	200	0	2000	20000	20000	0	20000	60000	-	budget surplus
488	500	300	0	2000	20000	30000	0	20000	70000	-	budget surplus
544	500	400	0	2000	20000	40000	0	20000	80000	-	budget surplus
599	750	400	0	2000	30000	40000	0	20000	90000	-	budget surplus
653	750	400	0	3000	30000	40000	0	30000	100000	-	budget surplus
703	750	400	667	3000	30000	40000	10000	30000	110000	-	budget surplus
757	750	500	667	3000	30000	50000	10000	30000	120000	-	budget surplus
809	750	600	667	3000	30000	60000	10000	30000	130000	-	budget surplus
859	750	700	667	3000	30000	70000	10000	30000	140000	-	budget surplus
908	1000	700	667	3000	30000	70000	10000	30000	140000	-	budget surplus
957	1000	800	667	3000	40000	80000	10000	30000	160000	-	budget surplus
1004	1000	900	667	3000	40000	90000	10000	30000	170000	-	budget surplus
1049	1000	1000	667	3000	40000	100000	10000	30000	180000	-	budget surplus
1092	1250	1000	667	3000	50000	100000	10000	30000	190000	-	budget surplus
1134	1250	1000	667	4000	50000	100000	10000	40000	200000	-	budget surplus
1177	1250	1000	1333	4000	50000	100000	20000	40000	210000	-	budget surplus
1217	1250	1000	2000	4000	50000	100000	30000	40000	220000	-	budget surplus
1260	1250	1100	2000	4000	50000	110000	30000	40000	230000	-	budget surplus
1302	1250	1200	2000	4000	50000	120000	30000	40000	240000	budget constraint	budget constraint
1343	1250	1300	2000	4000	50000	130000	30000	40000	250000	-	budget deficit

ource: designed by authors

Figure 6: The Report Regarding Local Budget Optimisation Based on Utility of Services

To summarise, the general algorithm is shown on Figure 7.



Source: designed by authors

Figure 7: Algorithm for the Management of Local Budget Expenditure

The software for the budget optimisations tasks is currently under development, therefore we showed an example based only on four types of services. Typically, a detailed local budget calculation requires the calculation of parameters for several thousand types of services depending on the size of the community.

5. Conclusions

The result of our research is a design to optimise local government expenditure according to the criterion of maximising utility for the inhabitants of the community.

The optimization process consists of two steps. In the first stage, the utility of the services provided by the local government to the citizens of a particular community is determined. The utility can be determined through a survey or analytically using a comparison with a benchmark. The choice of method should be consistent and transparent for the inhabitants of the community.

In the second stage, a computerised algorithm is applied. It calculates the marginal utility and determines the number of iterations. For each iteration, a combination of services is calculated, considering the utility maximisation and the budget constraint. The task is considered complete if the utility is maximised and the available funding is utilised as much as possible. The calculation process is adapted to the necessary changes in the number of services, their cost, and their utility.

The calculation process can be made completely transparent to the community by publishing it on the community website. It should be noted that this algorithm minimises the influence of politicians on decisions about the allocation of funds, so this approach can be considered as fair as possible to citizens and the most accountable. If necessary, additional constraints can be introduced into the model, such as a minimum allowable amount of funding for certain services.

Since the algorithm presented above is being introduced into the practice of local governments in Ukraine, we then see an assessment of the impact of the application of this algorithm on the efficiency of funds utilisation by local authorities as a prospect for further research.

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