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Management of local government finance in long-term; implementation of the satisficing behavior theory and multi-criteria optimization

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Abstract

A new procedure of management and policy formulation is presented which mirrors long-term thinking process and scenario analysis by local government financial managers. The method offers an approach linking long-term financial planning, performance measures and budgeting for results and outcomes, and includes learning during implementation of the decision supporting procedure. The procedure generates, with the utilization of local government (LG) finance model, alternative prognoses, based on H. Simon concept of multi-stage formation of aspirations related to goals, and searching for financial policies through modification of aspirations as search progresses. A reference point multi-criteria optimization technique is applied. The model describes financial flows and stock of the LG budget, includes fiscal rules and other budget restrictions, including liquidity, as the model constraints. Respective criteria are maximized, for instance cumulated investment, and minimized – debt service costs. The procedure is illustrated by numerical solutions based on Polish LG data.

Keywords: local government finance management, mathematical modeling, satisficing behavior theory, multicriteria optimization,

1. OBJECTIVE AND SCOPE OF ANALYSIS

The paper's objective is development of a procedure supporting finance management in long-term. We present a procedure that can help in long-term financial planning and budgeting, and in analysis of alternative financial policies regarding investment, fixed assets formation and debt. The procedure includes formulation of the local government (LG) budget model, which mirrors interrelations between financial variables – flows and stock over time. The objective of the optimization model implementation is to determine investment over a long-term and debt policies contributing to infrastructure development and services enhancement, tailored to the conditions of a given LG and consistent with existing legal regulations. The fiscal rules and other restrictions regarding operating budget balancing and budget liquidity are defined as constraints in the model. Solution of the model generates long-term projections of the model decision variables.

The procedure utilizes a computer system, with the budget model included, which implements Herbert Simon satisficing behavior (Simon 1947, 1955, 1959) and the multi-criteria optimization (Keeney and Raiffa 1976) theories It also includes learning in the process of decision making. The multi-criteria analysis implements the reference point methodology (Wierzbicki 1986, Wierzbicki et al. 2000), (Kruś 2008), which bases on the Simon's theory and utilizes the concept of formation aspirations of a decision maker (dm) in a multi-stage, adaptive way. Budget decision makers begin with available basic revenues, continue with a consideration of goals, and desired results (expressed by aspirations), and then, utilizing the model, conclude by deciding what values of the model decision variables best fit the desired results over a period of several years. The goals are adjusted during the process as the dm learns more about consequences of her decisions resulting from previous goals' selection and the model solutions.

The presented method combines financial planning and annual budgeting with strategic planning, and budgeting for results and outcomes, and is addressed to the European Union (EU) countries. The method presents a process of long-term thinking and policy formulation by financial management, which analyzes implications of actions taken today, and ensures budget balance and financial sustainability. The policy formulation method, with the utilization of the LG finance model, each year generates conditional projections of decision variables - a safe level of investment, disaggregated into investments co-financed by the EU funds and investments financed by the LG's budget, and a safe debt (medium and long term credits and bonds) for financing investment. These investments and debts ensure satisfaction of the model criteria: maximization of investment cumulated over an investment period, for example 2014-2023, and simultaneously, minimization of total costs associated with debt service after 2023, until all debts issued during 2014-2023 mature. Investment maximization is important for countries, *net* beneficiaries of the EU funds, and results from the desire of a select country to narrow the infrastructure gap between the country and the developed European economies. The assumed objectives will be valid in the current "EU programming period" – until 2022. After 2022, other goals, for example regarding controlling debt service and selecting infrastructure facilities supporting new technologies can be implemented.[1]

Long-term finance management and making informed decisions avoiding excessive indebtedness and investment is very important in cities and in national economies. We implement the developed procedure in a LG, but the procedure can also be applied to national economy models. Select model constraints, for instance regarding operating budget balancing and liquidity are valid both at the LG's and national levels.

Generation of long-term budget projections with implementation of the multi-criteria optimization model with fiscal constraints and formulation of fiscal policy based on H. Simon satisficing behavior theory is a novelty in the area of decision making in LG finance management.

[1] In 2012 Polish LGs were asked in a questionnaire about the objectives of their long-term finance management and planning. Above 60% of LGs answered that they had been, and would continue, acquiring large EU funds to invest - facilitate infrastructure development and enhance local services. Simultaneously, 44% LGs indicated other objectives – reduction of indebtedness and budget deficit. About 5% of LGs selected the single objective of liquidating the indebtedness (Cichocki 2013a). LGs in other EU countries might think similar about financial objectives over 2015-2022.

The computer-based iterative, interactive procedure, based on Simon satisficing behavior theory and multi-criteria optimization derives a Pareto optimal outcome, the criteria values, closest to the assumed, adaptively verified aspiration of the dm and calculates respective decision variables of the model. The dm modifies her reference points during the procedure as she learns more about possible outcomes and the feasible decision variables' values. Full sovereignty of the dm is assumed. She makes the final decision, selects the variables values regarding debt and investment that best fit her aspirations.

Select decision variables (solutions of the multi-criteria optimization model) are presented to illustrate the iterative procedure of the criteria and aspiration's verification. An impact of initial indebtedness (the LG finance model's initial parameter) on the Pareto solutions and financial policies are presented.

2. LONG-TERM FINANCE MANAGEMENT - PLANNING AND BUDGETING

Budgeting is arguably the most formalized and institutionalized process among all forms of policy making (Breunig 2006:1072). Long-term financial planning (l-tfp) process integrates budgeting and strategic planning and helps financial managers identify emerging problems – difficulties and opportunities - before they pass by. It enables the budget planners to recognize implications of present decisions and integrate policy choices into the budgeting process. Rubin (2014), writes: "contemporary budgeting includes complexity and variety of budget programs and structures, and the shift from annual discretionary programs to ongoing entitlements and l-tfp".

The presented method offers the dm a tool for construction of firm basis for decision making, helps politicians formulate policy goals, which are needed and expected by local societies, and enables them, based on alternative projections, building consensus for financial policy decisions. LGs must highlight situations for which a financial policy is needed today to avoid problems tomorrow – reevaluate their capital improvement planning when infrastructure needs in select future years exceed available revenues, or avoid decisions counter to its long-term financial interests. Kavanagh (2007) lists the most important benefits from l-tfp including: stimulation of long-term thinking about the budget process; clarification of strategic intent and advance recognition of potential problems; incorporation of financial perspective into organizational planning and imposition of discipline in budgeting procedure. Kaplan and Norton (1996) describe a financial perspective as one of four key perspectives for successfully realizing organization strategy and vision. Irene Rubin in the introduction to the book by Kavanagh (2007) writes: "During downturns in revenue, the struggle to balance the budget took precedence over planning". Lindblom (1959) suggested that budgets exhibit incremental changes. Policy and budgets' dynamics analysis was put forward by Baumgartner and Jones (2002), who explained that budgets result from policy choices that assume prior's year proportionally increased values plus random adjustments (sometimes extreme shifts within budget structure), called punctuations, resulting for example from elections of new governments or financial crises - see also

(Wildavsky 1964). Breunig (2006) offered a new understanding of budget punctuation as a stochastic process and extended explanation of Jones and Baumgartner (2005).

We investigate implications of fiscal policy decisions of a LG and the role of restraints in formulating fiscal policies with the support of a multi-criteria optimization model. LGs' decision makers can have several goals, and simultaneously take into account all fiscal restraints determined by law and conditions of budget balancing. Fiscal restraints have become an integral part of public finance in 76 countries (Schaechter et al. 2012) and usually reduce maximum spending. However, they have proven controversial. For example, they do not tackle extreme situations (financial crises), which are beyond governmental control, or, when not properly designed, are not effective – for example do not reduce debt (Cichocki 2013a, b), see also Fig. 8 in this paper. Supporters of fiscal restraints emphasize cutting short negative externalities imposed on future generations. Opponents argue that fiscal rules hinder the ability of governments to intervene in the economy when interventions are needed (Hallerberg et al. 2009), see also Fig. 9 and 10. Hughes Hallet and Jensen (2012) describe mechanisms for rule-based fiscal policy co-ordination for long-term soft debt targets as a means of addressing problems caused by excessive debt and suggest to replace the failed Stability and Growth Pact (SGP) imposed on governments in the euro area. They define rules for the general government (GG) – public sector that explain how fiscal authorities should behave in the future. Our approach can be used to analyze the policy, not only in the LG sector, but of the whole public sector - the GG debt and deficit. It can accommodate Hallet and Jensen mechanism and the Stability and Growth Pact imposed on governments in the euro area.

The presented method offers an approach linking strategic long-term financial planning, performance measures and budgeting for results and outcomes, and is a departure from the incremental budgeting (see also Jones and Baumgartner 2005 and the GFOA Recommendation 2007). It does not involve stochastic processes as presented by Citi (2013) with regard to *ex-post* analysis. Baumgartner and Jones (2002), Citi (2013), and Padgett (1980: 354, 359) emphasized methodological limitations of linear regression techniques widely used in analysis of budgetary dynamics.

The presented method of generating alternative prognosis, and searching for financial policies through modification of aspirations as search progresses - with application of the respective multi-criteria optimization technique, accommodates the approaches presented in literature. It basis on Simon's ideas of satisficing behavior and bounded rationality, and is influenced by ideas put forward by March (1991), and Levinthal and March (1993). March (1988) emphasized the adaptive character of aspirations and developed an argument that adaptive processes, with learning, explore new possibilities and exploit old certainties. In our paper the adaptive procedure regarding anticipation of fiscal policies includes exploration of things such as search, experimentation and flexibility, and during the decision making process allows the dm for risk taking. The explicit choices are based on calculated decisions about alternative cumulative investments and the cost of implementing these investments associated with debt. The higher are cumulated investments, the higher is the risk. Old certainties include the LG budget model relations, with the help of which upper and lower limits for elements of reference points (aspirations) are determined. The procedure ensures consistency and stability of preferences that are reliably assumed.

March (1991) states that the choice between exploration and exploitation emphasizes the role of targets or aspiration in regulating allocations to search. The usual assumption is that search is inhibited if the most preferred alternative is above the target. In satisficing behavior theory, (Simon 1955), and in prospect theory (Kahneman and Tversky 1979), the search is stimulated if the most preferred known alternative is below the target. In the presented procedure the search can be carried both, above the target indicated by a reference point and reflecting aspirations of the dm, and below the target.

Simon remarks, 1955, regarding substitution of a vector function for a scalar pay-off function in a decision-making process suggests implementation of the multicriteria approach. The constructed decision procedure, with the LG budget model included, allows for a change of aspiration levels in the sequence of trials - exploration of alternative outcomes and corresponding model solutions.

Reference-dependent preferences have been well accepted in decision sciences, experimental economics, behavioral finance, and marketing – see (Baucells, Weber and Welfens 2011). They studied the important problem indicated by Kahneman (1992) "how multiple reference points compete and combine", and experimentally documented "how subjects form their reference points as a reaction to a time series of prices". It is a step toward a descriptive model of reference-point formation.

In our paper the reference points are defined in the multicriteria space of outcomes. They represent goals as aspiration levels for particular criteria assumed by the decision maker. The dm initially has very limited information about possible outcomes, which can be calculated using the LG budget model implemented in a computer-based system. The reference points are used as a tool supporting the dm in looking for the preferred Pareto-optimal outcome in the criteria space. The dm finds the outcomes in an iterative, interactive learning procedure, and adapts her aspiration levels as the search progresses using information on obtained outcomes and decision variables. In (Blettner et al. 2015) a recursive feedback model of learning from organizational experience is proposed that explains heterogeneity of attention allocation to the reference points in a process of aspirations adaptation over time. In our paper the learning process draws on possible outcomes and the feasible decision variables in planning the LG budget, which results from solution of the model with adaptively modified aspirations.

The suggested procedure also embodies intertemporal comparisons. Outcomes are analyzed and compared for the whole analyzed period, and decision variables - in individual consecutive years of that period. The approach links resources to objectives at the beginning of the budgetary long-term planning processes, and the primary focus is on outcomes. It gives the dm (budget manager) time to analyze hypothetical results of her decisions and formulate appropriate responses. The process of aspirations' adaptation is fast thanks to the utilization of the LG budget model. It can be extended over time as the planning process (generation of the long-term financial plan) repeats every year. In this way the process is, in a way, similar to the recursive feedback model of learning (Blettner et al. 2015), who utilize past experience. Goal based learning was discussed also by Moynihan (2005). Theobold and Nicholson-Crotty (2005) analyzed multiple conflicting goals in public administration.

The budget's mathematical model bases on general framework of LGs' finance, debt management and capital improvement plans which often use debt financing (Bitner et al. 2013, Hallerberg et al. 2009, Kavanagh 2007; Casey and Mucha 2008; Rossi and Dafflon 2002; Cichocki, et al. 2001; Miranda, Picur 2000; Cichocki, Leithe 1999; Leonard 1996; Josef, 1994; GFOA Recommendations, 2013, 2010, 2007).

3. THE ROLE OF LOCAL GOVERNMENT IN PUBLIC FINANCE SECTOR

Local governments play crucial role in delivering services to the public. The tasks implemented by institutions of the LG sector include economic services – water, gas, energy supply, sewerage and solid waste management, construction and maintenance of roads and houses, and public services: education, health, social care, culture, leisure and public security. The LG sector in many countries is the largest public investor of the public sector, and simultaneously its contribution to the public sector debt and deficit is very small. The share of LG sector in public sector investment is high in many EU countries (in 2013: in Italy, 77%, France, 74.2%, the Netherlands, 68%, Japan - about 75%). In Poland, the share equals 58.8% in 2013, and is higher than the EU average (about 50%). Over 2009-2013 the LG sector investment is lower in the EU new member states (NMS) - about 43%, than in the old EU countries (EU15) - about 55%. In 2013 the share is low in Greece, Spain (about 30%), Austria, the U.S. (about 40%), Bulgaria (below 30%), Estonia - 43% (29% over 2010-2011), Hungary (below 40%), and Slovakia - 41%. In countries where LGs' investment expenditures were low prior to 2004, they grew fast; the average, over 2000-2013, yearly growth rate in Romania equals 37%, Latvia and Lithuania - 25%, Bulgaria - 22%. The investment expenditure, on average, constitutes 14%-22% of the LGs' total expenditure. This share is higher in the NMS than in the EU15 countries by about 6 - 8 pps. Many NMS, and select EU15 countries will seek, over 2015-2022, to acquire EU funds for financing infrastructure investment, and will remain the major investor of the public sector.

Simultaneously with the growing investment, the debt of LGs grew fast. However, it is not the LGs' sector, but the central government sector, which mostly contributes to the excessive public debt and budget deficits. For example, in Poland, the share of the LG sector debt in GDP in 2013 equaled 4.25%, while the public sector debt equaled 57.1% GDP. In 2013 the share of the LG sector deficit in

GDP equaled 0.18%, and the public sector deficit - 4.3% GDP. The share of the LG sector debt in GDP is low in the NMS (about 3%), with the exception of Latvia (above 5%). In the Scandinavian countries, France and Italy the share is about 8%; in Germany - 5,3%, in Spain - 4%, see (Bitner and Cichocki 2015).

4. MATHEMATICAL MODEL OF LOCAL GOVERNMENT BUDGET

4.1. Model description

The model encompasses various categories of financial flows: operating, capital and total revenues and expenditures, new debt, debt proceeds, and stock: indebtedness and fixed assets - defined each year of an investment period (Cichocki 2013a: 101). Some of them are exogenous in the model, other are decision variables and values computed based on these variables. Inter temporal relations between financial flows and stocks are described in the model as constraints. They include principles of sound financial management (budget liquidity, continuity of investment financing), and fiscal rules, introduced to avoid budget deficits and excessive debt issued by LGs - regarding limiting operating expenditures and debt service costs related to total revenue, calculated for each LG separately[2]. In the model we look for a maximum cumulated investment – summed up over a given period [t_1, T_N], which can be financed from the LG budget, the EU funds, and from debt. The model enables, each year, determination of a safe level of the LG's investment, debt and its structure - bond covenants and medium and long-term credits terms, and satisfaction of constraints. The debt can be issued in consecutive years, until T_N, and is structured in such a way that the cumulative costs of the debt service after T_N, until the debt is fully repaid, are minimized. The debt service includes repayment of debt principals (also of the initial debt issued prior to t_1), interest on the outstanding debt and guarantees given by a LG to other institutions. Repayment structure of debt results from the model assumptions regarding medium and long-term credits maturity and bond redemption. The debts are safe and legally justified, each year ensure budget liquidity, balance of operational accounts, and conform to fiscal regulations.

The budget model bases on general framework of LG' finance and debt management, fits current Polish legal regulations, and is consistent with the EU regulations. The investment (decision variable), contributes to the value of fixed assets (GFCF), which facilitate better services, but increases operating costs associated with maintenance of the existing assets; debt can increase investment, but must be repaid, and generates debt service costs. The implementation of the model and analysis of its solution helps budgeters make informed decisions regarding long-term investment and debt planning.

4.2. Model assumptions

[2] Fiscal rules may regard total outstanding debt, debt related to operational, or total revenue and other restraints, see (Kavanagh 2007:148-149, Cichocki, Leithe 1999).

The model is solved under several assumptions including exogeneoity of the operating revenues and the basic operating expenditures. Their arbitrary projections, use inflation, GDP growth rate and a local growth rate indicator projections. Interest rates for short, and long-term credits and bonds are assumed to be known. Select capital revenues: from sales of property and from capital grants are also exogenous. It is assumed that the EU funds can be used for financing investment only when a LG provides its own share from either its own budget surplus or/and from debt.[3] The obligatory share of a LG's budget in investments co-financed by the EU funds is fixed at 20% in the model, but can easily be changed for various model scenarios. We also assume an exogenous upper level for the EU funds which can be used for investment financing each year. This limit easily can be changed.

The time and value of various credits and bonds issues result from the model solution. It is assumed, for simplicity of interest calculation, that the debts' repayments and bonds repurchases, precede the issue of new debt, and take place instantaneously, on the 1st of July each year. Such simplification was for example assumed in the US law (2009-2010 Wisconsin States Annotations, 6703, p. 2).

Data utilized in analysis

Historical data of 2011-2013 are taken from a Polish LG financial report. The financial projections of operating revenues and basic operating expenditures over 2014 - 2023 are taken from official long-term financial projections of the LG, included in the database of the Ministry of Finance. They are exogenous in the model. Financial exogenous projections over 2024-2033 are made by authors.

4.3. Definition of the model variables

The model variables are defined for all $t \in [t_1, T_N]$ and are utilized for calculations at all time instants $t = t_1,.., T_N, T_{N+1}, T_M,$ where t_1 denotes an initial period of analysis, T_N is the last period of investment activity and debt issuance, and T_M is the last period of debt repayment - the end year of analysis; M > N are integers, number of years. Selection of T_M results from debt structure - bond covenants and loan repayment terms. The model starting point is a year t_0 – end of the year proceeding the budget year t_1. Values of variables at the end of t_0 and at the beginning of year t_1 are equal. The model decision variables in year t include:

- Inv^{EU}_t – investment expenditure co-financed by the EU funds
- Inv^{b}_t – investment expenditure financed by a LG budget and debt
- C^{lEU}_t, C^{lb}_t – medium term credits

[3] The EU regulation determines, for each individual project, the maximum share of co-financing with the EU funds at 85% of a total project value. LG's budget funds, debt, or both are used to cover the remaining 15%.

- C^{2EU}_t, C^{2b}_t – long-term credits
- B^{EU}_t, B^b_t, – medium term bonds,

where the superscript "EU" denotes financing jointly with the EU funds, and the superscript "b" - financing jointly with the LG own budget funds. The newly issued debt at time t is the summation of all credits and bonds (see (3a)).

4. 4. Formulation of the multi-objective optimization problem

The problem is formulated as maximization of investment cumulated over a period $[t_1, T_N]$, where $t_1 = t_0+1$, and, simultaneously, minimization of the total costs associated with debt service over $[T_{N+1}, T_M]$. Investments are implemented and debt is issued only over $[t_1, T_N]$. All debts are fully repaid in the analyzed period - until T_M. Mathematical formulation is as follows.

Given some initial values of the model variables and parameters at the initial time period[4] t_0, the time period $(t_1,\ldots,T_N, T_{N+1},\ldots,T_M)$, and exogenous projections of select variables over $[t_1, T_M]$, find, for every time instant $t \in [t_1,T_N]$, such values of investment expenditure, co-financed by the EU funds, Inv^{UE}_t, the LG budget, Inv^b_t, and new debt $ND_t = C^{1EU}_t + C^{1b}_t + C^{2EU}_t + C^{2b}_t + B^{EU}_t + B^b_t$[5], used for financing investment together with the EU funds, and with the LG own budget - which **maximize cumulative investment** over $[t_1, T_N]$, **and minimize** over $t \in [t_{N+1},T_M]$ the total **cost of servicing debt** issued for financing investment. Thus, we look for decision variables Inv^{EU}_t, Inv^b_t, C^{1EU}_t, C^{1b}_t, C^{2EU}_t, C^{2b}_t, B^{EU}_t, B^b_t, such that:

$$\sum_{t=t_1}^{T_N} Inv_t \ \textbf{\textit{is maximized,}} \tag{1}$$

where $Inv_t = Inv^{EU}_t + Inv^b_t$, $Inv^{EU}_t \geq 0$, $Inv^b_t \geq 0$, (1a)

and simultaneously

$$\{\sum_{t=T_N+1}^{T_M} [RD_t + Ir_t(\sum_{j=t_1}^{T_N} (\delta ND_j + \delta D_{0j}))]\} \ \textbf{\textit{is minimized}} \tag{2}$$

where

$C^{1EU}_t \geq 0$, $C^{1b}_t \geq 0$, $C^{2EU}_t \geq 0$, $C^{2b}_t \geq 0$, $B^{EU}_t \geq 0$, $B^b_t \geq 0$; (3)

RD_t denotes repayment of debt at time t, D_{0j} is the level of the outstanding initial (old) debt at time j, and $\sum_{j=t_1}^{t} \delta ND_j$ and $\sum_{j=t_1}^{t} \delta D_{0j}$ are the outstanding new and the old debt at time t. Debt repayment includes repayment of credits C^{1EU}, C^{1b}, C^{2EU}, C^{2b}, repurchase of bonds B^{EU}, B^b, issued starting t_1, and repayment of credits and bonds of the old debt.

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[4] For some excessive initial indebtedness D_{t0}, the model solution may not exist.

[5] Other bonds and credits can be included in the model.

The value of δD_t (δND_t) determines an increase in debt (new debt) outstanding during a year t; it can also be called *net* debt at t

$$\delta D_t = \delta ND_t + \delta D_{0t} = ND_t - RD_t = D_t - D_{t-1}, \tag{4}$$

where D_t and D_{t-1} are the total debt (new and "old") at the end of year t, and t-1 respectively. The debt repayment RD_t, includes exogenously given debt write-offs at time t (cancellations in account books – separately for each debt), which decrease the outstanding debt.

The debt outstanding at the end of year $t = t_1, t_2,\ldots,T_N$, equals the initial debt D_{0t} outstanding at outstanding at t, and cumulated *net* debt

$$D_t = D_{0t} + \sum_{k=0}^{t-t_1} \delta D_{t-k}. \tag{4a}$$

$Ir_t(\ )$ in (2) is the interest charged every period t on the total cumulated debt outstanding - all credits and bonds (see (8a), (9)).

The objectives (1) and (2) must be satisfied under constraints, which result from principles of financial management, and fiscal rules. In the model we introduce four such constraints for each $t \in [t_1, T_N]$. The first one, (5), ensures budget liquidity and continuity of investment financing in every year t. All cash receipts minus cash disbursements must be nonnegative - the revenue and expenditure forecasts and debt levels each year $t_1,..,T_N$ must ensure the LG balanced financial position

$$OpS_t + \delta D_t + CapRev_t + OthRev'_t + Nrb'_{t-1} - Inv_t \geq 0, \tag{5}$$

OpS_t denotes the operating surplus - operating revenues minus operating expenditures planned at time t, $OpS_t = OpRev_t - OpExp_t$. The operating expenditures include interest costs of the existing debt service and the fixed assets maintenance costs. The larger the OpS, the more funds available for financing investment. The values of OpS_t and δD_t can assume negative values, while the model variables $C^1{}_t$, $C^2{}_t$, B_t, and Inv_t - only positive values.

Receipts from the loan proceeds, δD_t, from other sources, $OthRev_t$, and from previous year budget current accounts' surpluses, Nrb'_{t-1}, are considered non-revenue at t, and serve to finance budget deficit. Likewise, the expenditure at t, does not include amounts allocated for the repayment of loan principal, RD_t - it makes up proceeds (non-expenditure). Other budget net inflows, $OthRev'_t$, are considered non-revenue, which finance budget deficit. They include for example inflows from privatization and capital shares owned by the LG, and other budget non-revenue outflows not associated with debt.

Capital revenues, $CapRev_t$, consist of three major parts: the EU funds (variables calculated in the model over $[t_1,T_N]$), and exogenously determined special capital grants and revenues from sales of property. The EU funds depend on the assumed level of the LGs own share required by the EU for all projects co-financed by the EU funds.[6].

Capital revenues $CapRev_t$, the operating surplus, OpS_t, and non-revenues: *net* debt proceeds, δD_t, other inflows, $OthRev'_t$, and funds from previous year, Nrb'_{t-1}, are used to finance investment.

The second constraint (6), ensures operating expenditures, which in a given year do not exceed operating revenues plus surpluses on the current accounts from the previous year. It is a modification, including the previous year surpluses, of the golden rule of finances, which states that the operating budget must be balanced (Cichocki 2013a, pp. 145, 179-180; Kavanagh, 2007, pp. 161-165; Rossi, Dafflon 2010; Daffflon 2002).

$$OpRev_t - OpExp_t + Nrb'_{t-1} \geq 0,\ t = t_1,..,T_N, \tag{6}$$

where the operating revenues are exogenously specified in separate projections for all sources of revenue.

The total operating expenditures $OpExp_t$ consist of two parts. Basic operating expenditures, $BOpExp_t$, which cover LG's statutory task and services, including labor costs, and expenditures which grow with new debt and investment - the interest, explicit costs of the existing debt service, and the fixed assets maintenance costs

$$OpExp_t = BOpExp_t + Ir_t\left(\sum_{j=t1}^{t} [\delta ND_j + \delta D_{0j}]\right) + \Phi_t \cdot GFCF_{t-1}. \tag{6a}$$

$GFCF_{t-1}$ denotes *gross* fixed capital formation (fixed assets) at t-1, and Φ_t is a ratio of the maintenance costs of the GFCF. New investments contribute to the value of fixed assets, but they generate increases in operating costs associated with the purchase of a new asset, maintenance of new facilities and capital purchases. $Ir_t(\cdot)$ is the interest cost of the outstanding initial debt D_{t0} at t, and of cumulative new debt outstanding at period t. Repayment schedule of D_{t0}, over $t_1,..,T_M$, is given - results from commitments made prior to time t_1. Revenue and operating expenditures projections are described in Kavanagh, 2007, ch. 6 and Cichocki, 2013a, pp. 59-70. GFCF at time t equals the GFCF value in previous year, plus new investment at t, minus the depreciation of GFCF at time t, minus sales of assets at t. The existing assets at t, $GFCF_t$ is decreased by depreciation and sale of assets at t, $SalGFCF_t$

$$GFCF_t = GFCF_{t-1} + Inv_t - d_t\,(GFCF_{t-1} + ½{*}Inv_t) - SalGFCF_t, \tag{6b}$$

where d_t is the fixed assets depreciation rate at t.

The current accounts balance at time t, Nrb'_t, defined in Polish law, includes two separate balances: the budget revenue and expenditure balance, and the debt account balance denoted Nrb_{t-1}. It

[6] One might consider several projection scenarios with various LG's own share, for example 25%, or 30%.

equals the balance from the previous year, Nrb'_{t-1}, plus debt receipts minus debt principals repayment at t, and revenues and expenditures balance from the previous year, NB_{t-1}, when it is negative

$$Nrb'_t = Nrb_{t-1} + ND_t - RD_t + NB_{t-1}, \text{ when } NB_{t-1} < 0, \tag{6c}$$

when $NB_{t-1} > 0$, we assume $NB_{t-1} = 0$. When a deficit occurs in previous year, $NB_{t-1} < 0$, then, the current account in year t must be compensated – the prior's year budget deficit is financed by additional debt. $NB_{t-1} = Rev_{t-1} - Exp_{t-1}$ denotes budget surplus when $NB_{t-1} > 0$, or budget deficit, when $NB_{t-1} < 0$. Rev_{t-1} is the total revenue, and Exp_{t-1} - the total expenditure at time t-1.

The third constraint (7), results from practice of financial management and requires non-negativity of the current accounts for all $t = t_1,..,T_N$

$$Nrb'_t \geq 0. \tag{7}$$

The fourth constraint (8), is a fiscal rule, imposed by the regulator of a given country to restrain LG's from excessive debt issuance. We implement the constraint currently used in Poland, imposed on the total debt service costs - debt repayment, interest on the outstanding debt, and payable guarantees, related to the total revenue at time t. These costs cannot exceed an affordable level, a limit, calculated for each LG separately, which depends on the past LG's performance: the average value, over three years preceding the year t, of the operating surplus enlarged by the revenue from sales of property, in relation to the total revenue[7].

$$[(RD_t + Ir_t(\sum_{j=t_1}^{t} [\delta ND_j + \delta D_{t0}]) / Rev_t] \leq$$

$$1/3 \sum_{i=1}^{3} [(OpRev_{t-i} - OpExp_{t-i} + SalGFCF_{t-i}) / Rev_{t-i}]. \tag{8}$$

The costs of debt service are calculated for each credit and each bond issue separately, on the debt outstanding at time t-1, plus new debt taken at time t, minus debt repayment at t. The interest costs are computed on the cumulative debt – the old debt and the new debt, credits and bonds outstanding at time t, as in (8a), (8b) and (8c). The value of the left hand side of (8), and of the limit for the total debt service (the right hand side of (8)), are calculated from the model. When, in any year of the period $[t_1, T_N]$, either the operating revenues will be lower than projected, or the basic operating expenditure higher than projected, then, the upper limit for the costs of debt service will be lower, and less debt can be issued in future years. In result, less EU funds can be acquired and lower investment implemented. The constraints (6) and (8) describe valid regulations in Poland[8]. The constraint (6) must be satisfied over $[t_1, T_N]$, and the constraint (8), over the whole period $[t_1, T_M]$, otherwise, the LG's

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[7] In order to calculate the limit for the costs of debt service at year t_1 (the right hand side value of (8)), one has to use data for t_1-1, t_1-2, and t_1-3, where t_1-1 =t_0. These data have to be known.

[8] Public Finance Law (Lpf), 2009, with amendments, art. 242, constraint (6), and art. 243, constraint (8). We can replace (8) with any other rule limiting debt in a given country.

council cannot approve the budget for a given budget year, and the obligatory financial plan for the three following years. These constraints can be easily changed in the model.

The total costs of debt service include all credits repayments and bond repurchases, the guarantees extended by a LG (included in the repayment of principal), and interest $Ir_t(\cdot)$ charged every period t on the total debt outstanding

$$DS_t = RD_t + Ir_t\,(\sum_{j=t_1}^{t} \delta ND_j) + Ir_t\,(\delta D_{t0}), \tag{8a}$$

where ND_j is the new debt (see 3a), and DS_{t0} is the initial debt service at the beginning of year t_1. The total interest on the new debt equals

$$Ir_t\,(\sum_{j=t_1}^{t} \delta ND_j) = Ir_t\,(\sum_{j=t_1}^{t} \delta C^{1EU}{}_j) + Ir_t\,(\sum_{j=t_1}^{t} \delta C^{1b}{}_j) + Ir_t\,(\sum_{j=t_1}^{t} \delta C^{2EU}{}_j) + Ir_t\,(\sum_{j=t_1}^{t} \delta C^{2b}{}_j) +$$

$$Ir_t\,(\sum_{j=t_1}^{t} \delta B^{EU}{}_j) + Ir_t\,(\sum_{j=t_1}^{t} \delta B^{b}{}_j). \tag{8b}$$

The debt repayment at t includes the repayments of the old debt, $(RD_{t0})_t$, resulting from commitments made prior to time t_1, and the cumulated new debt repayments – the four year credits, $RC^1{}_t$, the ten year credits, $RC^2{}_t$, and five year bonds, RB_t issued starting time t_1. The bond repurchase takes place once in five years.[9]

$$RD_t = (RD_{t0})_t + RND_t = (RD_{t0})_t + RC^1{}_t + RC^2{}_t + RB_t. \tag{8c}$$

The repayment of debt issued at year t, starts the next year, at t+1. Equal nominal credit repayments are assumed. The repayment schedule of the old debt results from bond prospectus and debt contracts concluded prior to time t_1.

When we assume that the debts' repayments and bonds' repurchases take place at the same time as the new debt issuance, on the 1st of July, then, the interest at time t can be calculated separately for each debt category, based on the cumulated debt at the end of the year t-1 (indebtedness at the beginning of t), and at the end of the year t - as in (9) for the medium-term credits C^{1EU}

$$Ir_t\,(\sum_{j=t_1}^{t} \delta C^{1EU}{}_j) = \tfrac{1}{2}\, ic_{1t}\,(\sum_{j=t_1}^{t-1} \delta C^{1EU}{}_{t-1} + \sum_{j=t_1}^{t} \delta C^{1EU}{}_t), \tag{9}$$

where ic_{1t} is the interest rate paid at t, on the medium-term credits $C^1{}_t$, and $\delta C^{1EU}{}_t$ is the outstanding credit $C^{1EU}{}_t$ at t with the interest rate ic_{1t}. This interest is summed up with the interest on credits C^{1b}, C^2 and the bonds B calculated with interest rates ic_{2t}, and ib_t (see (8b)). The formula (9) serves for calculation of interest charged for the total new debt issued at t and for the old debt.

The total revenue at time t, is the sum of the operating revenue, and the capital revenue

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[9] In the model, any time for bond maturity can be assumed. We assume five year bonds to better analyze the interrelation between these bonds and the four and the ten year credits.

$$Rev_t = OpRev_t + CapRev_t. \tag{10}$$

The operating revenues consist of basic revenues (several categories of tax revenues - PIT, CIT, VAT, property tax, fees and charges and intergovernmental transfers) and incidental operating revenues (one time revenues, for example earmarked operating grants).

The total budget expenditure at time t is the sum of the total operating expenditures and the capital expenditures - investment expenditures, and other capital expenditures, which can be neglected, as they do not significantly influence the model solutions

$$Exp_t = OpExp_t + CapExp_t = OpExp_t + Inv_t. \tag{11}$$

5. SOLUTIONS OF THE MULTI-CRITERIA PROBLEM

The optimal solution of the multi-criteria problem, and the model, allows to select each year of the period $[t_1, T_N]$, the level of investment, financed from the LG's budget, EU funds, debt and medium and long-term credits and bonds, which maximize cumulative investment over $[t_1, T_N]$, and simultaneously minimize the total debt service costs cumulated after the investment process, until all debts mature - over $[T_{N+1}, T_M]$. The LG finance model, which ensures budget liquidity and balance of operational accounts, together with the multi-criteria solution process is designed to support LGs' decisions regarding long-term finance management and planning – determination of affordable investment and a safe level of debt for financing the investments over the period $[t_1, T_N]$.

5.1. Multi-criteria optimization

The LG's manager thinks of two conflicting criteria: y_1 - the cumulative investment over $[t_1, T_N]$, and y_2 - the total costs of servicing debt over $[T_{N+1}, T_M]$. She looks for decision variables satisfying the model constraints (5)-(8) that maximize the criterion y_1 and, simultaneously, minimize the criterion y_2 [see (1) and (2)]. An increase in investment, facilitates usage of debt for projects' financing, and contributes to the increase of debt service costs.

The multi-criteria optimization problem is defined in two spaces: the first space of decision variables, $x = (Inv^{EU}_t, Inv^b_t, C^{1EU}_t, C^{1b}_t, C^{2EU}_t, C^{2b}_t, B^{EU}_t, B^b_t)$, and the second space of criteria $\mathbf{y} = (y_1, y_2)$. The model constraints define a set X_0 of the decision variables' admissible values in the variables' space. The optimization model relations define a set Y_0 of attainable values of the criteria, for which the domination relation is defined in the space $\mathbf{R}^2$ of criteria (y_1, y_2). A vector $y=(y_1, y_2)$ **weakly dominates** a vector $v=(v_1, v_2)$, $y \geq v$, where $y \in \mathbf{R}^2$, $v \in \mathbf{R}^2$, if $y_1 \geq v_1$ and $y_2 \leq v_2$. A vector $y=(y_1, y_2)$ **dominates** a vector $v=(v_1, v_2)$, $y > v$, where $y \in \mathbf{R}^2$, $v \in \mathbf{R}^2$, if $y_1 \geq v_1$ and $y_2 \leq v_2$, and $y \neq v$. A vector y **strictly dominates** a vector v, $y >> v$, $y \in \mathbf{R}^2$, $v \in \mathbf{R}^2$, if $y_1 > v_1$ and $y_2 < v_2$. The domination relation defines partial ordering in the criteria space, which is not a linear ordering. Therefore, traditional optimality concepts defined for one criterion optimization problems are not valid in the developed model.

A vector y is **Pareto optimal (nondominated)** in the set $Y_0 \subset \mathbf{R}^2$, if $y \in Y_0$ and there is no $v \in Y_0$ dominating the vector y. In the model, y is a two element vector. A vector y is **weakly Pareto optimal (weakly nondominated)** in the set Y_0, if $y \in Y_0$ and there is no $v \in Y_0$ strictly dominating the vector y.

Consistently with the theory of multi-criteria optimization (Keeney and Raiffa 1976; Wierzbicki 1986), we look for a solution (decision variables) which is Pareto optimal in the set Y_0. The Pareto optimal points in Y_0 and the corresponding decision variables in X_0 are not known, but they are uncovered in the computational solution procedure. Generation and analysis of achievable Pareto optimal outcomes is carried out with application of the reference point method, which utilizes the order approximation achievement functions (Wierzbicki 1986, Wierzbicki et al. 2000). Outcomes belonging the Pareto frontier are derived by solving the following optimization problem:

$$\max_{x \in X_0}[s(y(x), y^*)] \tag{12}$$

where: x – is a vector of decision variables, $y(x) = (y_1(x), y_2(x))$ - is a vector of criteria, which depends on the decision variables x through the model relations. The criterion y_1 is the investment cumulated over $[t_1, T_N]$, and y_2 is the total debt service cumulated over $[T_{N+1}, T_M]$.
A vector $y^*=(y_1^*, y_2^*)$, $y^* \in \mathbf{R}^2$, is a reference point defined by the aspiration levels for the criteria y_1 and y_2 assumed by the dm; $s(y,y^*)$ – is an order approximating achievement function. In the developed model, with objectives (1) and (2), the achievement function takes the following form

$$s(y, y^*) = 1- \{(1/2)\{ [1-s_1(y_1, y_1^*)]^p+[1-s_2(y_2, y_2^*)]^p \} \}^{1/p}, \tag{13}$$

where

$s_1(y_1, y_1^*)= (y_1- y_1^*)/(y_1^{up}-y_1^*)$, $s_2(y_2,y_2^*)= (y_2^*- y_2)/(y_2^* - y_2^{lo})$, and
p is a given integer number $p>2$, $y^d= (y_1^{up}, y_2^{lo})$ is a given point dominating the ideal point y^I defined by the maximal attainable value of y_1 and the minimal attainable value of y_2.

The decision maker, assumes a reference point y^* in the criteria space, and solves the optimization problem (12). The achievement function (13) has the property that its maximization leads to the Pareto-optimal point when the aspiration levels both overestimate and underestimate the attainable outcomes. It means that the reference point can be inside or outside the Y_0 set. The corresponding Pareto optimal solution, including point y^p, all decision variables, and other variables of the model, is derived as the solution of the problem (12).

The approach bases on the Simon's satisficing behaviour theory and, supported by a computer based system, interactively, in a number of iterations finds a solution that satisfies the dm aspirations. In each iteration the dm defines her aspirations as a reference point in the space of criteria. Then, using the optimization solver, the system derives a Pareto optimal outcome closest to the reference point, and calculates respective decision variables. The derived solution, including decision variables and values of the criteria, is presented to the dm for analysis. In consecutive iterations the dm collects information about attainable Pareto optimal outcomes, and adaptively modifies aspirations, as she uncovers the set of outcomes. Finally, she finds the preferred outcome corresponding to her aspiration - is satisfied with a good-enough solution.

Steps of the procedure, can be represented as follows:

Step 0. The **dm** sets exogenous variables and initial data of the model.

Step 1. The computer-based system (**cbs**) solves the optimization problems:

1. a.: maximize y_1, expression (1), with respect to the decision variables x, subject to the model constraints

1.b.: minimize y_2, expression (2), subject to the model constraints.

The model solutions: the decision variables, obtained values of the criteria and other outcomes of the model are saved in a data base.

The iteration number is set at $i = 1$.

Step 2. The **dm** analyzes and compares the solutions stored in the data base.

Step 3. The **dm** assumes a reference point – a vector defined by an aspiration level for the criterion y_1, and the criterion y_2.

Step 4. Using the reference point method the **cbs** maximizes the achievement function (12), with respect to the decision variables $\mathbf{x}$, subject to the model constraints and additional constraints of the reference point method.

The reference point and the model solutions are saved in the data base.

Step 5. The **dm** analyzes the current solution, compares it with the previous solutions.

In the 1st iteration the **dm** compares it with the solutions obtained in Step 1.

Step 6. The **dm** decides whether she is satisfied with the current solution.

If yes, then end the procedure,

if no, then the number of iteration $i = i+1$ and go to the Step 2.

Remarks regarding the procedure.

Steps 3 – 6 in the procedure can be repeated in a sequence of iterations. The computer-based system solves the optimization problems of the Steps 1 and 4, and stores solutions in a data base. The steps 0, 2, 3, 5 and 6 are made by the dm. The dm assumes exogenous variables and initial data of the model in the initial step 0. She assumes the aspiration levels in step 3, makes analysis of the solutions derived by the computer-based system and makes the final decision regarding ending of the procedure. Full sovereignty of the dm is assumed.

The dm is not fully aware of her preferences when she starts analysis of the multicriteria optimization problem - she does not know attainable outcomes. In the first step of the procedure the optimization problems: 1.a., 1.b. are solved. The solutions of the problems analyzed in Step 2 of the procedure, define a first approximation of the Pareto set of attainable outcomes. Having the solutions 1.a., 1.b. the dm knows that the set of possible Pareto optimal outcomes should weakly dominate the solution of the problem 1.a. and be weakly dominated by the solution of the problem 1.b. She has to adapt her aspiration level and select a reference point which ensures that the derived solution of the problem (12) belongs to the set of points weakly dominating the solution of the problem 1.a. and is weakly dominated by the solution of the problem 1.b. The system derives a new solution for a new reference point in Step 4.

In Step 6 the dm decides whether she is satisfied with the solution, or not. If the solution does not satisfy her, she has to modify the aspirations. She goes to the next iteration – to Step 2 and compares all the solutions generated by the system.

She looks for two solutions, between which she could find a new outcome according to her preferences. Let the solutions be denoted by y^{li}, y^{ui}, such that y^{ui} dominates y^{li}, $y^{li}<y^{ui}$, where i is the current iteration number. She modifies her aspirations and assumes in the Step 3 a reference point for which a new solution is derived by the system in the interval between the solutions y^{li}, y^{ui}. The interval is defined as the set of attainable outcomes dominating y^{li} and dominated by y^{ui}.

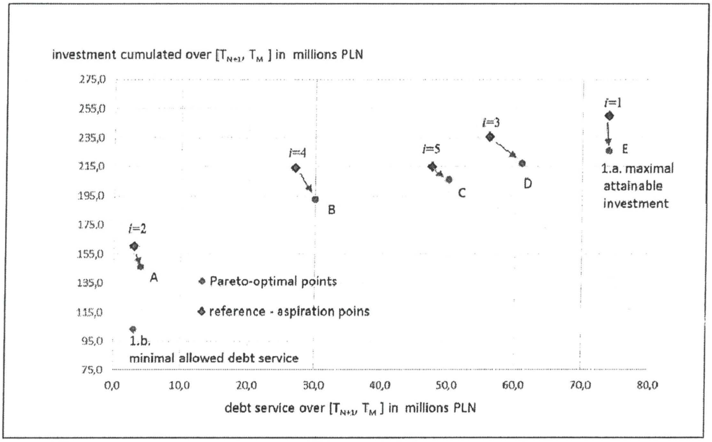
Thus, a sequence of solutions is derived by the procedure in which the aspirations are adapted as optimization proceeds in a consecutive iterations. The dm uncovers more information about the set of Pareto-optimal outcomes (and corresponding decision variables). The number of the derived outcomes increases. The solutions y^{li}, y^{ui} between which the dm looks for a new solution are changed, so that the interval between them decreases in consecutive iterations. The iterations are repeated until the dm will find the outcome which fits her adapted aspirations.

5.2. Pareto optimal solutions; outcomes of the satisficing behaviour procedure

In Fig. 1. we present select model solutions of the multi-criteria optimization problem (12): reference points (rhombic points) used in the computational procedure, and the vector valued outcomes of the procedure - the sum of investment over 2014-2023, and the sum of the debt service costs over 2024-2033. Points A, B, C, D and E are the problem's outcomes in the procedure, they belong to the Pareto frontier of the admissible set $\boldsymbol{Y}_0^1$, see Fig. 2, and are obtained in consecutive iterations. Additionally, in Table 1. select characteristics of the model solution over 2014-2023 are presented: the sum of EU financed investment, the new debt issued during 2014-2023 and debt used for the EU financed investment, the cumulated operating surplus, the maximum debt outstanding and the GFCF.

A decision how much to invest in the future is crucial for local development. Investment is also a driver of debt issuance and debt service costs. Assumption of a reference point can be associated with LG investment needs regarding infrastructure and services as one element of a reference point vector. One could consider several investment scenarios, depending on an attempt to satisfy given degree of investment needs and future LG's revenue, population, tax potential, economic growth and creditworthiness.

Fig. 1. Select model solutions



Source: done by authors[10]

In table 1 we present reference points, outcomes and the model select decision variables for initial debt D_0. These values are in millions PLN, but in the table and in the text we omit these units.

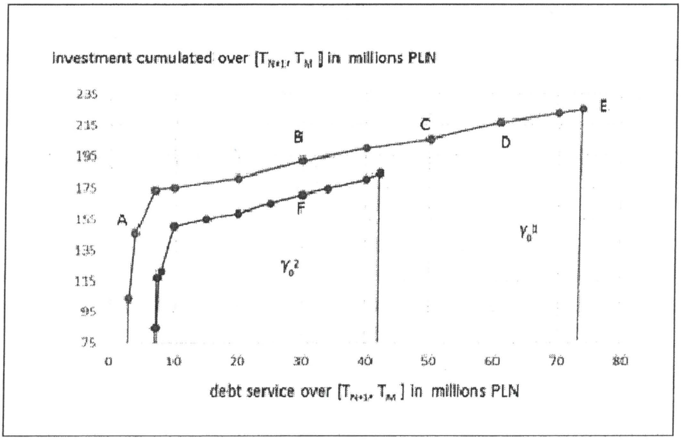
Table 1. Outcomes, reference points and select optimal Pareto solutions

Results of the procedure										
	Reference point		Pareto-optimal outcome			*Additional characteristics of select model solutions*				
	Sum of invest-ment over 2014-2023	Total debt service over 2024-2033		Sum of invest-ment over 2014-2023	Total debt service over 2024-2033	Sum of EU invest-ment over 2014-2023	Sum of new debt over 2014-2023 (new debt: EU invest-ment)	Sum of operating surplus: 2014-2023	Maximum outstan-ding debt	GFCF in 2024
1.a				226.0	73.9					
1.b				103.5	3.0					
i=1	250.0	75.0	E	226.0	73.9	78.0	80.0 (15.6)	52.2	64.6 in 2023	196.4
i=2	160.0	3.0	A	146.0	4.0	62.6	25.2 (12.5)	57.5	27.1 in 2016	124.9
i=3	235.0	56.1	D	217.1	61.0	79.5	69.1 (15.9)	53.2	53.2 in 2023	189.3
i=4	215.0	27.0	B	195.0	30.0	94.1	45.5 (18.8)	51.9	30.3 in 2022	167.0
i=5	215.7	47.5	C	205.0	50.0	101.1	63,4 (20.2)	49.3	44.5 in 2023	174.9

[10] All figures are done by authors; calculations based on a LG data.

The solution procedure starts from determination of limits, defined by the model and its constraints, for elements of outcome (and a reference point vector) – a minimum value of the debt service costs over 2024-2033 and a maximum value of the investment cumulated over 2014-2023 (steps 1a. and 1b. of the procedure). These upper limits will constitute thresholds which cannot be broken. Suppose the dm tries an ambitious goal of reducing 100% gap between the currently financed projects and the projects identified as necessary over 2014-2023, and assumes the reference point of 250 in investment and assessed 76 of debt service. This is her initial aspiration and she assumes the values of 250 and 76 as elements of the reference point vector. She obtains the Pareto solution E with outcomes equal to the limits obtained from solution of the maximization problem of step 1a.

Fig. 2. Pareto optimal frontiers of the model solutions for different initial conditions.



The dm analyzes not only the obtained values of the criteria but also the decision variables in consecutive years. The optimal Pareto solution E of the model yields very low investment (the decision variable) in 2014 and 2015, which strongly decreases in 2018 (Fig. 3). In addition, no EU funds for financing investment in 2015-2016 are utilized (Fig. 4.). Such a solution, although ensures the investment cumulated over 2014-2023 much larger than in other solutions, might not be acceptable in practice. Some investment projects will have to be continued in 2014 and 2015, and the funds provided by the budget, without any EU funds, might not be sufficient to continue these investments. The debt cumulated over $[T_{N+1}, T_M]$ is very high, and the debt service costs reach the limit in 2026-2028 (Fig. 7). There is a risk that in the solution E very high cumulated debt issued over 2014-2023 will generate very high total debt service costs over 2024-2033, which, although satisfy a constraint imposed in the model as a fiscal rule, may not guarantee budget liquidity during this period – repayment might not be possible in select years.

Therefore, in the second iteration the dm tries a very conservative reference point, in which investments planned for 2014-2023 equal 160 - 75% of the investments implemented over 2007-2013, and the debt service costs result from the debt issued prior to 2014 (3) – to find lower limits for the debt service costs over 2024 -2033, and the investment cumulated over 2014-2023. The procedure yields outcome A – 146 in total investment and 4 in the debt service costs over 2024-203 - the Pareto solution characterized by the model optimal decision variables which satisfy all fiscal rules and other model constrains. The total debt issued during 2014-2023 is 25,2, and the fixed assets (GFCF) in 2024 equal 124,9.

The decision maker is not satisfied with the decreasing investment values, especially during 2020-2023 (Fig. 3.), and the GFCF value in 2024. She looks for solution in the interval between A and E. She could increase investment and debt incrementally and safely remain in the admissible set $Y_0^{\,l}$. Still, the debt service costs are well below the limit (Fig. 7). Since the needs for the GFCF in 2024 and investment are higher, in the third iteration the dm assumes the reference point of 235 and obtains the Pareto solution D, with the total debt of 69.1, but similarly to the solution E, zero EU funds in 2015-2016 (Fig. 4.) and very low investments in 2014 and 2015. She has to lower her aspiration and selects the reference point of 214 cumulated investment, which equal the investment over 2007-2013. She obtains the Pareto solution B. The total investment over 2014-2023 equals 195, the GFCF equals 167 (Fig. 5.). Financing the investments requires 20.3 more debt than in A, and the total debt service costs, over 2024-2033, are by 26 higher.

The dm wants to maximize the investments, and tries to finance additional investment with debt. In the fifth iteration she looks for solution in the interval between B and D. She selects the reference point of 215 in investment and 47,5 in total debt service, higher than in B. The dm obtains the solution C and is satisfied with it. She stops the procedure. Such a choice will decrease the operating surplus because the debt service costs will increase. The decision variables of the solution C are acceptable, they do not have deficiencies of the solutions D and E. The cumulative investments are 205, by 10.0 higher than in the solution B (7 for the EU funded investment), and the GFCF is by 7.9 larger. The debt issued during 2014-2023 is by 17.9 larger and the debt service costs over 2024-2033 are higher by 20. Investments of the point C presented in Fig. 3 and debt (Fig. 6) will be implemented.

The set of candidates for solutions which will satisfy the dm has decreased during the process thanks to knowledge about attainable Pareto outcomes and the solutions obtained in the iterations 1-5 when the aspirations were corrected.

The Pareto solutions E and D of the model are much more risky, than the solutions represented by points A, B and C. Especially the solutions E, located on the edge of the admissible set $Y_0^{\,l}$ and the Pareto frontier, is very risky. A slight change in exogenous projections, of for instance operating revenues, might shift the solution outside the admissible set. When it happens, the constraint (8) will not be satisfied and no new debt can be issued. There would be no possibility to continue the investments which had been started because of insufficient funds.

In section 6.1. we present the model select decision variables for points A (y_1=146; y_2=4), B (y_1=194.7; y_2=30), C (y_1=204.5; y_2=50), and E (y_1=225.7; y_2=73.8), located on the Pareto frontier of the

Y_0^1 set, obtained for the initial debt D_{t0} = 15. In section 6.2. we compare solutions of the point B, and the point F (y_1=170.8; y_2=30) - located on the Pareto frontier of the Y_0^2 set, obtained for the higher initial debt of 35.4.

6. PRESENTATION OF DECISION VARIABLES

6.1. Decision variables - optimal solutions of the model; points A, B, C and E

In figures 3-10 projections generated by the model - the Pareto solutions A, B, C and E are compared, all with the initial debt D_0 of 15. These are optimal solutions which satisfy the model constraints (5)-(8), maximize the investment expenditures cumulated over $[t_1, T_N]$ and, simultaneously, minimize the total debt service costs cumulated over $[T_{N+1}, T_M]$.

The investment expenditures, the share of investment in total LG's expenditures, and the share of the EU co-financed investment in the total investment expenditures, over the planning period, from t_1 = 2014 to t_N = 2023, are volatile for the Pareto point E, when the cumulated investment is higher than for the point C (Figs 3. and 4.).

Fig. 3. Investment expenditures related to total expenditures

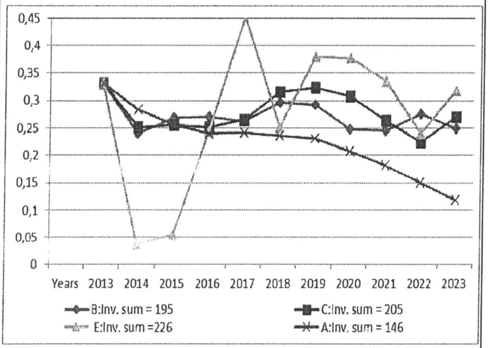
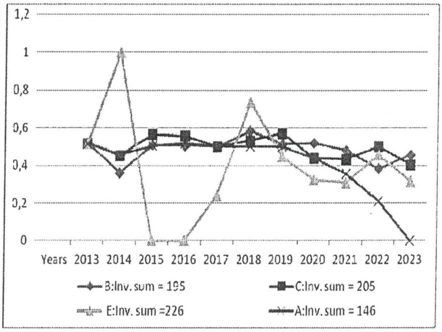


Fig. 4. Investment expenditures co-financed with the EU funds to total investment



The new debt outstanding and the old debt, issued prior to t_1 for the Pareto points B and C are presented in Fig. 6. The old debt is repaid in 2025, the new debt - in 2032.

The fiscal rule of the Polish law on public finance (Lpf) requires that the total debt service, including repayment of debt principals, in relation to the total revenue is below the statutory limit when the debt service associated with debt financing projects co-financed with the EU funds is excluded. The debt service with such exclusions, in relation to total revenue, and the limits defined by the Lpf (right hand side of (8)) are presented in Fig. 7. The limit for the total debt service with the exclusions is slightly higher than for the debt service without exclusions, because the operating expenditures are lower. The total debt service with exclusions to revenue is below the statutory limits for the Pareto solutions A, B, C, D and E. In E, the debt service costs grow in the period 2023-2028, equal the limit in 2026-2028, and sharply decrease in 2029. In solutions B and E the total debt service with exclusions to revenue is close over 2014-2020 and 2029-2033. The debt service without exclusions, for the solution E grows very fast in 2014 and 2020-2021, but in 2016-2020 is lower than for the solution B - it results from the lower debt outstanding.

Fig. 5. Gross Fixed Assets Formation

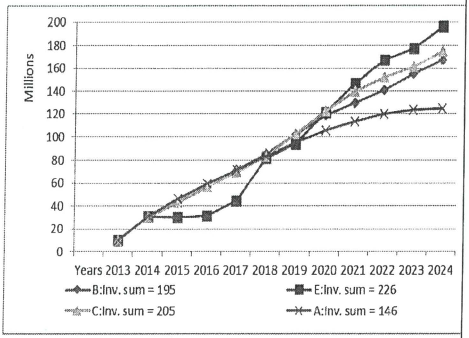
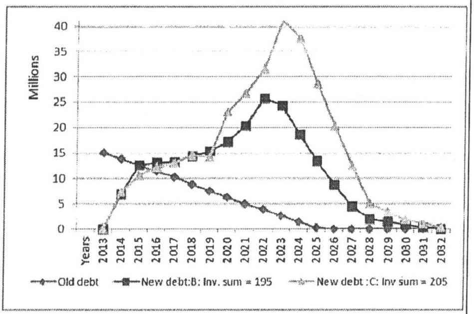


Fig. 6. Outstanding old and new debts



In the solution E the debt outstanding and the debt to total revenue grow very fast starting 2021 as a result of decreasing operating surplus. The debts in the solutions B and C are similar until 2019, then the debt in C grows – results from the larger debt service allowed after 2023 (Fig. 8.).

The share of the operating surplus in total revenue is higher for the Pareto solution E than for the solutions B and C, but starting 2021 it falls sharply because of the declining operating surplus (Fig. 9) - debt and the GFCF grow fast from 2021 on, and the operating expenditures rise. In Fig. 10. we show, that the existing fiscal rule hinders the LG's falling operating surplus (Fig. 9) and thus a decreasing potential to finance investment.

Fig. 7. Debt service with exclusions of debt for EU investment to total revenue

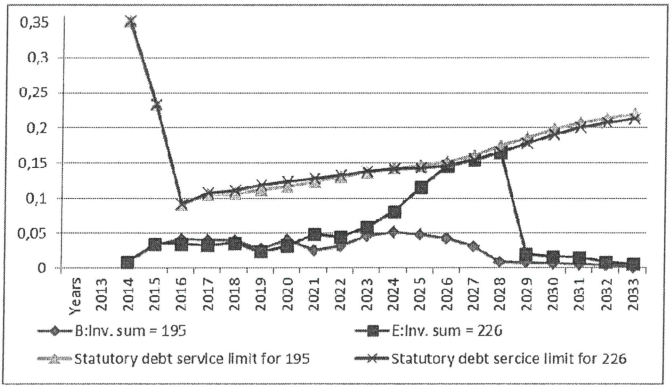


Fig. 8. Total outstanding debt

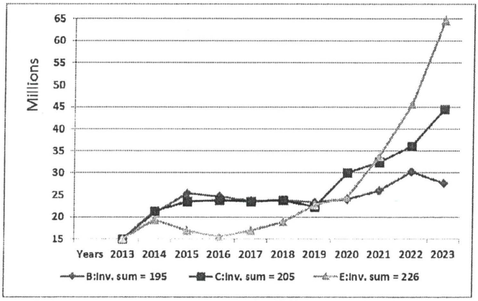


Fig. 9. Operating surplus to total revenue

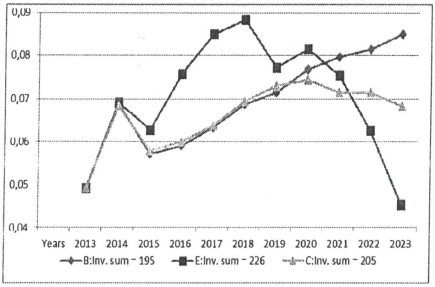
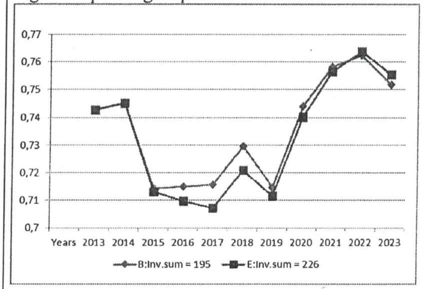


Fig. 10. Operating surplus with exclusions to revenue



6.2. Comparison of solutions for various LGs initial financial position

In figures 11 - 13 we present select variables of the two Pareto optimal solutions (B and F) of the optimization problem (1)-(2), with four constraints (5)–(8), defined for each t of the investment period $[t_1, T_N]$. The solutions are located on different Pareto frontiers, in different sets $Y^1{}_0$, and $Y^2{}_0$, as they are obtained for different initial indebtedness (Fig. 2.). Point B corresponds to the solutions of the model with the initial debt D_{t0} of 15, while the solution F is obtained for the higher initial debt of 35.4. To make the results comparable, the Pareto solutions B and F have the same costs of debt service cumulated over $[T_{N+1}, T_M]$ equal 30.

The Pareto solution F with the higher initial debt allows for lower investment. More money is needed for servicing debt. The sum of investments over $[t_1, T_N]$ equals 170.8, while for the solution B - 195. Investment in relation to total expenditure is shown in Fig. 11. The debt outstanding and the debt service over $[t_1, T_N]$ are higher for the point F than for B. The debts in 2023 are equal for the both solutions, because we assumed that the debt service over 2024-2033 is the same for them. For the F solution the debt service costs grow with an exception of 2020-2022, while for the solution B the costs grow in 2015-2016 and 2023 (Figs 12.-13.).

Fig. 11. Investment expenditures to total expenditures; various initial debts

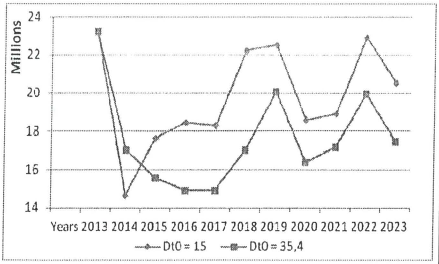


Fig. 12. Total outstanding debt; various initial debts

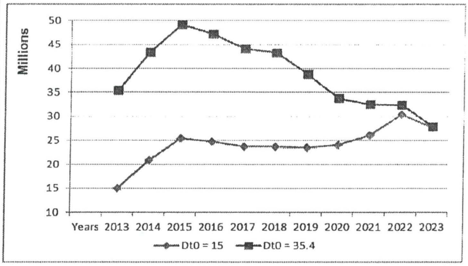
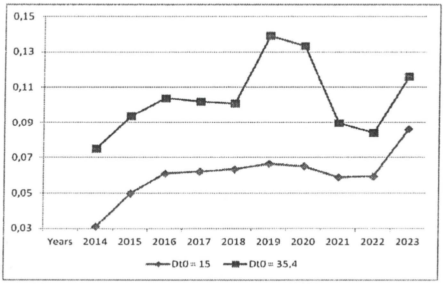


Fig. 13. Debt service to revenue; various initial debts



Higher debt service of the Pareto solution F results in a decrease of the operating surplus, and yields lower investment, and lower GFCF. Starting 2022 the fixed assets maintenance costs become very high for B, and the operating surplus to revenue is higher for the solution F than for B - operating expenditure grow.

7. Summary and Conclusions

We present a new procedural method of management local government finances in long-term. The procedure, which includes a mathematical LG budget model supports financial planning and financial policy formulation. It enables generation and analysis of alternative policies regarding investment and debt, which facilitate the infrastructure development and services enhancement. The budget model reflects interrelations between financial flows and stock over time. Fiscal rules and other restrictions regarding for instance budget liquidity are included as constraints in the LG policy optimization model. Solution of the model generates an outcome and long-term projection of decision variables which satisfy the decision maker – a financial manager. Affordable investments, disaggregated into co-financed by the EU funds and investments financed by the LG's budget and debt, and a safe debt (credits and bonds) are projected. These investments and debts ensure joint satisfaction of the model criteria: maximization of investment cumulated over an investment period, 2014-2023, and simultaneously, minimization of the total costs associated with debt service costs after 2023, until all debts mature.

The method enables selection of various goals updated during the policy formulation procedure, and generation of scenario variables associated with these goals. The iterative procedure bases on H. Simon satisficing behavior theory and the reference point method of multi-criteria optimization. In each iteration of the procedure the dm defines aspirations (related to goals) - required values of the model criteria represented by reference points. The computer-based procedure, derives an outcome closest to the reference point, and calculates respective decision variables. The dm is independent, modifies her reference points during the procedure as she learns more about possible outcomes and the decision variables. She makes the final selection of outcome and decision variables that best fit her updated aspirations. All outcomes resulting from the model solution are Pareto optimal.

Formulation of alternative financial policies based on Simon's concept and looking for modified goals as search progresses, with the utilization of the LG finance model and multi-criteria optimization is a novelty in literature. The method accommodates approaches presented in literature - incremental and punctuated budgeting, budget's dynamics analysis (Lindblom 1959, Baumgartner and Jones 2002, Breunig 2006), its stochastic verification (Citi 2013), and the optimization model with constraints (Cichocki 2013a, and b)[11]. The extensions of the presented method in comparison with those cited in the literature include: simultaneous consideration of several goals; implementation of Simon's concept of multi-stage formation of aspirations related to goals, and selection of satisificing financial policy with application of multi-criteria optimization and learning; extension of the period of analysis until all debts' maturity; analysis of fixed assets, and explicit inclusion of medium and long-term credits and bonds.

The presented method of analysis mirrors a process of long-term thinking and policy formulation by financial management. It supports long-term financial planning, helps investigate implications of actions taken today and offers the dm a tool for analysis of hypothetical results of her decisions and formulation of appropriate responses. The method allows clarification of strategic intent, formulation of alternative policy goals and advance recognition of potential problems - situations for which a financial policy is needed today to avoid problems tomorrow. For example reevaluation of capital improvement planning when infrastructure needs in select years exceed available revenues. It also offers a chance to discuss opportunities and financial policies which should be implemented. The method links long-term financial planning, performance measuring and budgeting for results and outcomes, and allows learning during implementation of the procedure.

[11] Cichocki formulated and solved the model in which he maximized total funds, from budget and debt, for financing investment, subject to constraints - provided one optimal solution. Each period, upper limits for safe and legally justified debt and investment were determined.

The presented solutions based on Polish LGs data give evidence that investments should be planned very carefully because the fixed assets and their maintenance costs grow very fast, and the operating surplus falls dramatically (see solution E in Figs 5. and 9). Simultaneously, the debt grows very fast and the debt service reaches the limit during 2026-2029 (Figs 7. and 8.). When the goals are too ambitious, investments and associated debt are very high in consecutive years. One obtains investments, implementation of which could encounter difficulties. The model constraints are satisfied, but the investment policy is impractical and the dm prefers the solution C to the solutions D and E - Figs 3. and 4.

The implementation of the method can be two fold. It can support decisions made by LGs' managers regarding long-term financial planning – determination of affordable level of investment, EU funds, and a safe level of medium and long term debt each year of a planning period. A dm can analyze consequences of her decisions regarding investment, formation of fixed assets and debt until its maturity. The method can also be implemented by central government and legal authorities to analyze alternative fiscal rules impact on LGs' debt, deficit and investment. We have shown, using the iterative procedure and the model, that the rules formulated in Polish law are neither effective, nor efficient. Many LGs can satisfy the rules and their debt will double during 2014-2023, see also (Cichocki 2013a). Simultaneously a substantial number of LGs, will not be able to use the EU funds over 2015- 2023 because the legal constraint, (8) in the paper, will prohibit debt issuance. The existing rule hinders the growing debt and decreasing operating expenditures. Future analysis could include relaxation of select rules, for example limitation of the debt service costs, and sufficiency of the golden rule of finances in LGs' sector, see (Dafflon 2002). The model assumptions are consistent with the Polish law, however, country specific assumptions can be incorporated in the model, and after simple verifications the method could be implemented in many EU countries, also for analysis of debt in the public sector. One should emphasize clarity of the results presentation – a feasible set Y (space of decision variables: investment and debt service costs). Having this set, it is evident that cities (countries like Greece), which generated huge debt could not invest in a planned period. The only Pareto solution for them would be a point on the horizontal line in Fig. 2 with a given debt service costs and zero cumulated investment.

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