CHAPTER 9

Social entrepreneurship as a driver of green remediation and revitalization of affected territories: digital modeling and decision support systems

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Abstract

In the conditions of post-conflict transformation of Ukraine's territories, the issues of environmental restoration, legal transparency, and the involvement of social entrepreneurs come to the forefront in the context of sustainable development. In the present study, an integrated decision support system (DSS) has been developed and tested, in which social entrepreneurship acts as the main agent of changes. The methodological foundation of this work relies on the Triple Bottom Line (TBL), the ESG concept, which provides the operational level of measurable indicators: the *E* and *S* metrics for environmental and social results, as well as the *G* component (governance), which was implemented through a LegalTech module for the purpose of codifying the compliance requirements of smart contracts and maintaining an immutable audit trail. The empirical verification of the model was carried out on the example of the Kharkiv region, where 6 scenarios of digital integration were simulated. For visual-analytical evaluation, a Dendrogram of clusters (Dendrogram), a Parallel Coordinates Plot (PCP), and a Butterfly Chart diagram were used, which made it possible to reflect the degree of influence of digital solutions on TBL indicators, as well as to assess the degree of their influence on management efficiency. The scientific novelty of the study lies in the development of a digital model of integrative management of the processes of green remediation and revitalization of post-conflict territories relying on the tools of social entrepreneurship, which makes it possible to achieve end-to-end managerial visibility because it makes it possible to stitch together all links of the chain – data → analytics → selection → legal

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execution → cash flow → confirmed effect – into a single, verifiable orchestration. For the development of social entrepreneurship this has enormous significance, since it turns "good intentions" into contractible, financeable, and replicable projects with demonstrable impact and fair competition.

Keywords

Post-conflict transformation, green remediation, revitalization, social entrepreneurship, Decision Support System (DSS), Triple Bottom Line (TBL), ESG concept (Environmental, Social, Governance), LegalTech, GIS visualization, multicriteria analysis, simulation modeling, environmental sustainability.

9.1 Introduction

In the first quarter of the twenty-first century, the concept of restoration of territories affected as a result of military conflicts has acquired particular relevance, covering not only aspects of the physical reconstruction of objects of the housing stock and infrastructure, but also deep transformations of socio-economic, environmental, and managerial systems. Most acutely these challenges at the present moment manifest themselves in Ukraine, where, as a result of full-scale military actions, the basic life cycles of territorial communities have been disrupted, key elements of infrastructure have been destroyed, lands and water bodies are polluted, social contradictions have intensified, as well as the vulnerability of certain groups of the population. In such conditions of multifactor hybrid anthropogenic negative impact, the engagement of fundamentally new nonstandard approaches is necessary, which will be able to ensure not only the elimination of pollution from military activity, but also to form the foundations of innovative and sustainable development of the country and its regions. In this context, strategies of green remediation and revitalization acquire special significance, called upon to minimize the negative impact on the environment, restore ecosystems, stimulate economic activity, while maximally engaging social cooperation on the principles of responsibility and solidarity [1, 2].

Unfortunately, it is possible to state the fact that the projects being implemented at present in the regions testify to the predominant prevalence of fragmentary, disjointed managerial decisions, not connected into a single system and not ensuring the maximally possible synergistic effect. A significant part of such projects is focused on the rapid elimination of the consequences from military activity, while long-term social, economic, and environmental risks often remain without due attention. The management models used for the restoration of affected territories are

predominantly oriented toward a vertical structure of decision-making, which are minimally aimed at the involvement of the local community and civil structures, and also insufficiently integrate modern digital technologies. This, unfortunately, leads to inefficient use of resources, duplication of functions, a low level of monitoring and control of the transparency of processes.

Social entrepreneurship, that is, entrepreneurial activity with clearly verified social and environmental goals of functioning, are increasingly considered by scholars and practitioners as an active instrument of sustainable development of local territorial communities. In many countries such enterprises have already proved their effectiveness as catalysts of regional recovery, thanks to the prompt and effective mobilization of resources, the maximally possible use of the existing potential, the attracting of attention to the projects of the local community. To a large extent thanks to their initiatives, the most acute environmental, social, economic, and political problems of a specific region "are exposed", which need the attracting of attention to them by the broad public. However, despite the presence of positive cases, their potential in the sphere of remediation and revitalization of territories affected by military conflicts remains to a significant degree unused due to the absence of systemic mechanisms of support, legal incentives, and digital tools ensuring scalability and coordination of efforts.

In the context of this it should be emphasized that the concepts of green remediation (environmentally careful elimination of pollutions of various kinds) and revitalization of territories (complex socio-economic revival of the affected territories) must occupy a central place in the strategies of post-war restoration of Ukraine. At the same time, their successful implementation cannot be implemented without large-scale use of digital technologies – from instruments of monitoring, modeling, forecasting and geoinformation systems to decision support systems (Decision Support Systems, DSS), ensuring the expediency of the use of resources, the transparency of the undertaken actions, and the observance of regulatory-legal obligations [2].

Social entrepreneurs today are recognized as a driver of positive changes in cities, regions, and in the country as a whole, taking on the solution of acute social and environmental problems by innovative methods. Unlike traditional business, the goal of social enterprises is not only profit, but also a measurable socially useful effect. Research confirms that social entrepreneurs are able to satisfy the collective needs of communities, contribute to the improvement of the quality of life of the population, and stimulate economic growth at the regional level. That is why especially relevant is their role in urban modernization, reconstruction, and revitalization. In particular, the realization of European cases demonstrates that

social enterprises successfully take upon themselves the management of such projects as the restoration and revival of abandoned industrial zones, turning old factories and wastelands into cultural, educational, as well as popular modern business spaces [3].

Thus, social entrepreneurship acts as a kind of linking link between economic development, social progress, and environmental sustainability. In studies of recent years, it is noted that it is precisely social enterprises that are capable of achieving a synergistic effect at the intersection of economic growth, social justice, and protection of the environment. According to estimates of international experts, at present in the world there are about 10 million social enterprises, which generate in total on the order of 2 trillion USD of revenue and create up to 200 million jobs. All this reflects their significant contribution to global economic and sustainable development. In the context of the restoration of territories after military conflicts and other emergencies of natural and technogenic character, social entrepreneurs often act as initiators of changes "from below", relying on the knowledge of the local community, territorial specificity, allowing the maximal use of the potential resource of the local community in the implementation of socially and environmentally significant projects. As world experience shows, social entrepreneurship is capable of simultaneously solving environmental problems and creating new opportunities for the revitalization of affected territories [4].

The aim of the present research is the development of the theoretical-methodological structure of a digital model of integration management of the processes of green remediation and revitalization of post-war territories with reliance on the instruments of social entrepreneurship, modern DSS and LegalTech platforms, and its approbation.

Within the framework of the designated goal the following research tasks were defined: analysis of the transformations of post-war territories and identification of the key challenges, trends, and needs determining the specifics of green remediation and social entrepreneurship under the conditions of post-conflict recovery; identification of the possibilities and advantages of the integration of DSS, LegalTech, as well as platform models for the purpose of optimization of coordination, management, as well as scaling of the projects of remediation and revitalization of the affected territories; formation of the architecture of the digital model, combining digital modeling of the processes of remediation and revitalization, supporting decision-making, legal support of the projects implemented by the subjects of social economic activity; approbation of the model on the example of a selected case from among the most affected regions of Ukraine and, at the same time, the most active region with developed social entrepreneurship.

9.2 Theoretical and methodological basis of the research

First of all, it should be indicated what is meant in the present research by the concept of "social entrepreneurship" (SE). A comprehensive analysis of publications devoted to various aspects of such activity allows it to be defined as economic activity which is predominantly directed at the solution of social and environmental problems by means of the application of innovative business approaches. Social entrepreneurship, according to the definition of Defourny and Nyssens, represents economic activity directed at the solution of clearly defined social and environmental problems, where profit acts not as a goal, but as a means of achieving sustainable socio-environmental impact [5].

It is fundamentally important to emphasize that social entrepreneurship radically differs from traditional entrepreneurship, whose main goal is the obtaining and maximization of profit, including the satisfaction of the needs of the market, etc. Unlike traditional business, social entrepreneurship is characterized by an integrated approach, where commercial activity serves not only as a means of economic growth, but also as an instrument for solving complex social, environmental, and humanitarian challenges, thereby contributing to the sustainable development of communities and territories.

Proceeding from this, it is possible to draw the conclusion that, within the framework of the problematics relevant for post-conflict territories, the activation of activity and the scaling of social entrepreneurship (along with the development of traditional entrepreneurial activity) can facilitate a faster and environmentally careful territorial restoration of territories, at the same time creating new jobs, maximally involving local communities in the process of remediation and revitalization, introducing at the same time sustainable practices for achieving social, environmental, and economic effect. Together with this, care for future favorable post-war development ties together the use of methods of green remediation and progressive methods of revitalization of the affected territories, which cover a totality of interrelated processes, namely:

– ecological, such as the cleaning of contaminated soil, water, and air with the use of technologies minimizing the impact on the environment [6];

– infrastructural restoration of objects of infrastructure taking into account the principles of sustainability, such as the use of renewable sources of energy [7];

– social processes of involving local communities in the revival of the infrastructure of subjects of education, the creation of jobs, and the improvement of the quality of life of the population on the restored territories [8].

Social entrepreneurship, namely entrepreneurial activity with clearly verified social and environmental goals, as was mentioned earlier, in many countries plays

the role of an effective instrument of the sustainable restoration of the development of the territorial socio-economic system. The studied world experience of the above-mentioned circle of interrelated issues contains many illustrative examples, presented in **Table 9.1**.

Table 9.1 World experience demonstrating the effectiveness of social entrepreneurship in the restoration of territories after conflicts, natural disasters, and environmental crises

Region/Country	Year	Description of the case	Effect of social entrepreneurship
Rwanda	1994	Program "One Cow per Poor Family" for the distribution of livestock to poor families	Reduction of poverty from 60% to 30%, ensuring sustainable sources of income, coverage of thousands of families, growth of regional GDP
USA, New Orleans	2005	Initiatives after Hurricane Katrina: restoration of schools (Doris Vuatye), return of the Vietnamese community (Father Vien), Propeller incubator for the implementation of startups	Return of 2000+ pupils and students to study, 90% return of the local population, 1000+ jobs, growth of the regional economy
Japan, Tohoku	2011	Programs of restoration after the earthquake: Tohoku Kaikon (magazine and CSA model), Otsuchi-Sashiko (embroidery), MORIUMIUS (educational center), Canyons (tourism)	16,000+ subscribers, 785,000 USD of revenue, 60 thousand+ jobs, employment for 33 thousand women, development of ecotourism, expansion of the scale to 22 regions
Philippines	2011	Programs after Typhoon Haiyan: Gawad Kalinga (housing), employment and restoration of infrastructure	3000+ houses, reduction of poverty by 10–20%, creation of new jobs, increase of the resilience of the affected territory
Nepal	2015	Field Ready (3D printing for humanitarian needs), UNDP (off-grid solar solutions)	10,000+ units of PPE, training of 100+ manufacturers, energy for 5000+ households, strengthening of the economy
Rwanda, Kenya, Ethiopia	2017	Inkomoko: support of entrepreneurs-refugees through training and microfinancing	Support of 15,000+ entrepreneurs, growth of incomes by 30%, strengthening of the regional economy
Lebanon, Beirut	2020	Live Love Recycle: separate collection and recycling of waste after the explosion in the port	Recycling of 1000+ tons of waste, creation of jobs, restoration of the urban environment
Cambodia, Ukraine	2022–2023	APOPO: demining with the use of animals; Promprylad.Renovation (Ukraine): volunteering and initiatives of restoration of territory [9]	Clearing of 100M+ m^2 of land, 200+ jobs, return of agricultural lands to operation, restoration of objects of infrastructure

By the authors of the monograph, the state and trends of the development of social entrepreneurship in Ukraine in recent times were studied in depth. Thus, in the period of military activity many social enterprises demonstrate the ability to integrate economic activity and volunteer activity with social responsibility, thereby strengthening social cohesion, increasing environmental awareness, and the economic potential of the local community. As of 2023–2025, in Ukraine there is no unified official statistics on the number of functioning social enterprises due to the vagueness of their definition and the absence of a special legal status. According to official estimates, in 2020 about 1,000 social enterprises were operating in the country [10]. Growth of their number by 82% in the period from 2014 to 2020 was conditioned by the socio-economic crisis caused by the annexation of Crimea, the war in Donbas, the appearance of new vulnerable groups and the necessity of satisfying their primary needs (it is about refugees, ATO veterans, socially unprotected groups of the population, etc.), as well as economic stagnation. In 2023–2024 social entrepreneurship became activated in response to the full-scale invasion of Russia, focusing on the support of temporarily displaced persons, military personnel and veterans, as well as on the restoration of the affected territories and the destroyed objects of infrastructure. It should be noted that the absence of a legislative base limits the popularization and scaling of social entrepreneurship, however initiatives such as for example EU4Youth promote its development through training projects and grants. State support remains weak, and financing is more often provided by grants (27%) and own revenues (54%) [11]. Social enterprises, such as Veteran Hub, demonstrate positive results in the integration of veterans, creating sustainable business models with their active participation. Online platforms, such as Diia.Business, provide free consultations and courses, supporting new entrepreneurs. However, for the purposes of the further effective development of such a type of activity, there are necessary, first of all, clear legislation, support of the government, a unified digital platform, incubators, and metrics for measuring their social impact [12].

In the opinion of the authors of the monograph, in addition to all of the above, for the systemic and balanced development of SE, ensuring a long-term effect, a stable conceptual basis is necessary. Such a basis can be the TBL concept, uniting three interrelated components:

– economic sustainability (Profit) – financial viability of projects, stimulation of development, above all, of the regional economy;

– social sustainability (People) – improvement of the well-being of the local population, as well as the creation of conditions for social inclusivity and justice;

– environmental sustainability (Planet) – minimization of the negative impact on the environment and implementation of measures for the restoration and

protection of natural resources, which directly correlates with the principles of "green" remediation.

The TBL (Triple Bottom Line) concept, proposed by John Elkington in 1994, focuses attention on harmonious and balanced development through three dimensions: economic, social, and environmental sustainability. The British entrepreneur and consultant on sustainable development developed TBL for the assessment of the activity of organizations not only on the basis of financial results, but also by their impact on society and the environment. The concept received wide recognition in the 2000s, becoming a basis for assessment including also for social enterprises and sustainable business models [14].

Thus, let's consider that social entrepreneurship organically integrates all three components of TBL, at the same time ensuring their implementation in practice, especially under the conditions of post-conflict restoration of the affected territories [15, 16].

In the conviction of the authors of the present research, the ESG concept (Environmental, Social, Governance) is a direct consequence, continuation, and operationalization of the TBL concept [17]. This concept was first presented to the public in 2004 in the UN report "Who Cares Wins", where to business and investors the idea of the integration of environmental, social, and governance factors into strategy for ensuring long-term sustainability was proposed [18]. In the context of the present research, the ESG use will allow social enterprises to track in detail and manage the processes of remediation and revitalization, ensuring a high degree of transparency, efficiency, and attractiveness for external investors and stakeholders with the help of a set of concrete, measurable indicators, namely:

– environmental (environmental aspect) – indicators of the reduction of the level of pollution, restoration of ecosystems, waste management, efficiency of the use of resources, and others;

– social (social aspect) – indicators of employment, integration of vulnerable groups into the local community, social trust, involvement of the territorial community in the solution of socially significant issues, improvement of the living conditions of the population, and others;

– governance (managerial aspect) – transparency, quality of management, efficiency of the distribution of resources, compliance with legal, ethical, environmental, and other norms.

In order to integrate and effectively use ESG criteria in projects of green remediation and revitalization of territories affected by military activity in projects of social entrepreneurial activity, it is necessary to implement the corresponding digital technologies and instruments. In the context of the aggregate of questions

raised in the present research, such possibilities are provided by decision support systems (Decision Support Systems, DSS) and LegalTech platforms, namely:

– collection, visualization, and analysis of data on the state of objects and the affected territory in real time;

– constant monitoring of the observance of ESG criteria and the principles of TBL;

– rapid response to changes of external conditions, as well as forecasting of risks with the possibility of operative correction of strategy;

– increase of transparency, accountability, as well as trust on the part of the local population, bodies of local self-government, donors, and investors.

In the conviction of the authors, digital modeling, DSS with platforms built into a single digital model can become those instruments that will unite social entrepreneurship, green remediation, and revitalization into a single integrated management system, based on the principles of ESG and TBL.

Summarizing all of the above, let's present the methodological framework of the research (**Fig. 9.1**).

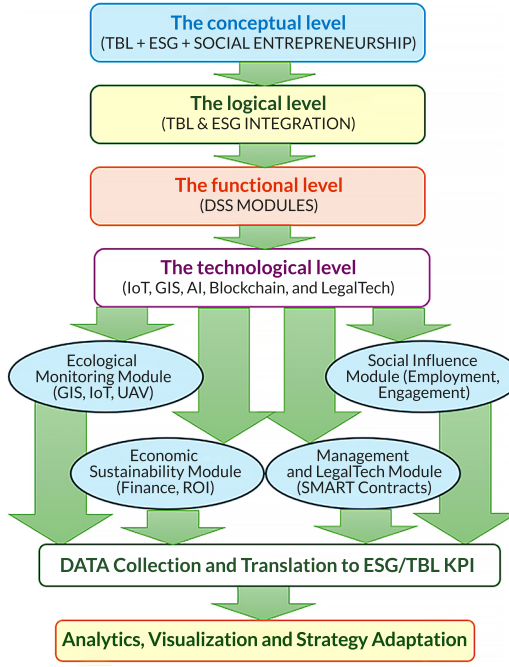

Fig. 9.1 Methodological framework of the study

The proposed architecture of the digital model integrates the TBL and ESG concepts with social entrepreneurship tools, creating a multi-level management system for green remediation and revitalization of post-conflict territories.

The conceptual level sets the methodological foundation, combining TBL (economy, society, ecology) with ESG (Environmental, Social, Governance) to provide a holistic view of sustainability.

The logical level formalizes the interrelation between ESG and TBL, allowing it to be adapted to post-conflict conditions.

The functional level is implemented through DSS modules, each responsible for monitoring ecology, assessing social impact, analyzing economic sustainability, and controlling management processes.

The technological level ensures the operation of the system using IoT, GIS, AI, Blockchain, and LegalTech.

Thus, in the present research the effective implementation of a complex of measures for green remediation and revitalization of post-conflict territories should be considered with reliance on social entrepreneurship in conjunction with the ESG (Environmental, Social, Governance) concept and TBL (Triple Bottom Line). Within the framework of the described methodology, the TBL concept sets three key dimensions – economic, social, and environmental – as balanced in the assessment of the sustainability of projects implemented by subjects of social entrepreneurial activity. In its turn, ESG expands these dimensions, including the institutional-managerial aspect (Governance), which in TBL is not directly singled out, but is critically important for the restoration of post-conflict territories. In the model under consideration, the *E*-component of TBL (ecology) can be detailed through the *E*-block of ESG (in particular, with the help of indicators of pollution of soil, water, air, and restoration of the biocenosis, etc.). The *S*-component of TBL (social) is strengthened by the *S*-block of ESG indicators, which allows one to formalize a comprehensive assessment of social inclusion, employment of vulnerable groups, and the assessment of the level of public involvement in the processes of remediation and revitalization. The economic block of TBL can be realized through ESG metrics of indicators reflecting long-term economic sustainability and the distribution of benefits among stakeholders who will participate in the processes of restoration of the affected territories. The addition of the *G*-component in ESG ensures the assessment of the level of transparency, accountability, and control of the overall effectiveness of managerial processes, including LegalTech tools and mechanisms of anti-corruption control. Thus, in the vision of the authors of the research, TBL sets a structural "triangle" of sustainability, and ESG fills its dimensions

with operationalized metrics, including managerial ones. In the conviction of the authors, the integration of ESG and TBL will make it possible to build a multilevel system of comprehensive assessment, where each of the three components of the TBL concept is supported by concrete ESG indicators relevant to post-conflict restoration and the further revival of the territory. Within the framework of DSS such integration will be able to ensure a more precise, transparent, and controllable digital model, applicable both for local and regional, and for international monitoring.

9.3 Integrated digital model: architecture and characteristics of functional blocks

The aim of the digital integrated model is the support of the selection and implementation of portfolios of projects of green remediation and revitalization of post-war territories with reliance on social entrepreneurship, with measurability within the framework of the ESG concept, evaluation in the logic of TBL, transparent management by means of LegalTech, spatial binding through GIS, and provable "end-to-end managerial visibility".

Methodologically it is possible to synthesize the Mixed Methods approach, digital convergence, and triangulation. The architecture of the digital model will also include a Data Mesh of socio-geospatial and contractual data, robust normalization and accounting for the polarity of indicators, AHP/ANP weighting with calibration, explainable predictive analytics (GBDT/LSTM/GAM), scenario analysis with MCDA, multi-period optimization of the portfolio of projects (with precedence UXO → remediation and CVaR risk), and GIS assessment of spatial effects.

The general characteristic of the structural elements of the unified digital model proposed by the authors and their formalization is presented in **Table 9.2**.

The data of the table demonstrate how each module of the digital model (data → indexes → weighting model → MCDA → optimization → LegalTech → GIS → monitoring) is supported by formulas and tied to goals/threshold values. The aim of the authors of the monograph was to develop such a digital model that the key parameters and the obtained results of the projects could be instruments of management by means of the visualization tools used: Butterfly Chart (for the visualization of progress/gaps), Parallel Coordinates Plot (PCP) (for the visualization of profiles by the scenario and utility-U), Dendrogram (for the visualization of clusters). In the conviction of the authors, this will make it possible to ensure end-to-end managerial visibility and reproducibility of effective solutions.

Table 9.2 Architecture and formalization of the digital model by modules (end-to-end contour)

Layer/module	Purpose	Key inputs/parameters	Mathematical formalization
Data Mesh (S/E/I/C/G)	Integration of data	*S*: register of social enterprises (id, NAICS/NACE, region, FTE, SROI, capex/opex); *E*: soil, water, air, UXO, biodiversity, coords; *I*: donor, amount, instrument; *C*: contracts (id, value, terms, awardee, social_enterprise, milestones, payments); *G*: land use, damage, access, grid	–
Cleaning from pollution and normalization of the territory	Comparability of scales and robustness	Pollution, standards, units of measurement, standards	Robust z-score: $z = (X - \text{median}(X))/IQR(X)$; scale to [0,1]; inversion for "↓ better": $X+ = 1 - \text{scaled}(X)$
Indexation ESG → TBL	Indexes of branches and KPI	Indicators *E*1…*E*5, *S*1…*S*4, *P*1…*P*5, *G*1…*G*5	$E^{\backslash^*} = \sum j\, w_{E,j}\, E_j^{norm}$, similarly for *S**, *P**, *G**; $\sum jw\_(.), j) = 1$
Weighting model	Prioritization of branches	Top-level weights $(\alpha, \beta, \gamma, \Delta)$	$CR \le 0.10$; monotonic constraints; log of versions of weights. For the pilot project: $\alpha = 0.35, \beta = 0.25, \gamma = 0.25, \Delta = 0.15$
Definition of utility (MCDA)	Compensatory evaluation of scenarios	*E**, *S**, *P**, *G**, weights	$U(s) = \alpha E^*(s) + \beta S^*(s) + + \gamma P^*(s) + \Delta G^*(s)$; ranking of scenarios *S*1…*S*6; leaders: *S*6, *S*4/*S*5
LegalTech (Governance)	Transparency and control over the fulfillment of contracts	Events of tender/contract, templates of smart payments, risk assessment, rules	$LT_{(C)} = \lambda_1 1_{e-tender} + \lambda_2 1_{e-contract} + + \lambda_3 smart - \lambda_4 P(violation) \cdot Impact$; subject to the hard constraint $x_{rem} \le \sum_i x_{UXO,\, i}$
Forecast + XAI	Forecasts of KPI and their explainability	Time series S/E/I/C/G; scenarios	GBDT (Cat/XGB) + LSTM + GAM; conformal intervals; SHAP/ICE
Optimization of the portfolio	Selection of x^* by years/clusters	Budgets *Bt* deadlines T_{max}, thresholds, fairness	x^*, roadmap, plan of KPI payments
GIS integration	Spatial analysis	Geometries of projects, logistics, determination of problem zones	Cost-distance, overlay/clip, zonal statistics
Monitoring/visualizations	Control of progress	Base 2026H1, goals 2030, facts/oracles	Butterfly Chart, PCP, Dendrogram, dashboards of G-metrics. Progress toward goals by KPI; profiles *E**, *S**, *P**, *G**, *U* clusters *C*1–*C*3
Validation/assessment of readiness of the model	Check of quality and compliance with current tasks	DQ, MAPE, ECE, fairness, lead-time, PDK	Threshold criteria: DQ, MAPE, ECE, P(PDK); P(\mathrm{PDK}) and others

9.4 Approbation of the integrated digital model on the example of Kharkiv region (Ukraine)

Kharkiv region remains one of the most active ecosystems of social entrepreneurship in Ukraine: despite the proximity to the zone of hostilities, in the region there function on the order of 100–150 SE (estimate for 2024), predominantly supported by international donors (such as USAID, EU4Business, the "Renaissance" Foundation, etc.) and local infrastructure (including the Union of Entrepreneurs of Kharkiv region, the initiatives of the regional military administration, etc.). Undoubtedly, the military situation restrains the scaling of the development of SE, however, along with this, confirms also the popularity of the given business model in the region [19].

Below in **Table 9.3** the passport of the ecosystem of social entrepreneurship of Kharkiv region is presented.

Table 9.3 Passport of the ecosystem of social entrepreneurship (identification card, 2024)

Parameter	Description	Comment/sources
Region	Kharkiv region, Ukraine	Approbation of the pilot for DSS/LegalTech/GIS
Period of the baseline assessment	2024 (calendar year)	Used as the baseline cut before the launch from H2-2026
Number of social enterprises	≈ 100–150	Indirect estimates from open sources
Key directions of social entrepreneurship	Inclusion, ecology, education/culture, social assistance	Profiles are used for the setting of *S*-metrics
Examples of initiatives	"Wardrobe of Good" (2017–2024, assistance to pregnant women and unprotected groups of the population); cooperatives for waste processing	Illustrative cases of the ecosystem
International support	USAID (micro-grants ~ 20 thousand USD for SMEs with a social mission); EU4Business (up to 25 thousand EUR); Renaissance Foundation	Channels of financing and SROI data
Created infrastructure	Union of Entrepreneurs of Kharkiv region; departments of the regional administration (social protection)	Consulting, training, legal support
Current constraints of the development of SE	Proximity to the front, martial law → risks, logistics, deficit of resources	Important inputs for CVaR and planning
Relevance and completeness of the data	2024–2025; partial coverage	For the purpose of filling gaps – requests to the regional administration/donors
Main open sources of information	Nakipelo.ua; USAID; EU4Business/USF; Renaissance Foundation; YouControl	For the purpose of verification and updating of the passport

In the opinion of the authors of the monograph, the data of the SE passport of the region selected for approbation can be organically embedded into the previously formed digital model, namely:

– *S*-layer (social entrepreneurship): entry of data into the register of SE and their profiles → employment of target groups (*S*1), participation in the project of the local community (*S*2), social assistance and support/training/rehabilitation of groups of the population in need of this (*S*3), localization of procurements for the implementation of projects (*P*3 through counterparties of social entrepreneurship);

– *C*-layer (contracts): determination of the main channels of financing and implementation of procurements → e-tender/e-contract, smart-coverage (*G*2/*G*3), LT risk scoring (*G*4), lead-time (*G*5);

– *E*-layer (ecology): projects of social entrepreneurship in the context of elimination of pollution from military activity/reconstruction/green remediation of territories affected by military activity → integration into the metrics *E*1–*E*5 and the coverage map $Z(x, y)$;

– *I*-layer (investments): financial and humanitarian assistance/grants/microfinancing → trajectory of CAPEX/OPEX and pay-for-impact scenarios.

In the opinion of the authors of the monograph it is necessary to clearly designate the boundaries and the regime of approbation of the digital model:

1. Start of works: not earlier than H2-2026; planned horizon until 2030.

2. The necessity of distinguishing key scenarios, namely, 6 scenarios of digital integration (*S*1–*S*6) with different share of SE and LegalTech coverage:

– *S*1 – Bio/Phyto: focus on bio- and phytoremediation [20]; basic LegalTech (e-tender), a moderate share of participation of subjects of social entrepreneurship;

– *S*2 – Remed + Green Housing: remediation + construction/modernization of "green" housing for temporarily displaced persons and for returned residents of Kharkiv region; basic LegalTech coverage;

– *S*3 – Remed + Inclusion + LegalTech: remediation with a priority of social inclusion (employment of vulnerable groups of the population, access to receiving services of education [21], medical aid and medical servicing of all groups of the population [22]) and reinforced LegalTech (e-contract, KPI payments);

– *S*4 – Multi (eco + energy + agro + LT + DSS): intersectoral package (ecology, the use of alternative sources of energy [7], revival of the agro-industrial potential [23] with integrated DSS and LegalTech; balanced portfolio;

– *S*5 – Circular/Energy & Water Reuse: projects of circular economy (connected with recycling, industrial symbiosis, etc.), reuse of water/energy; smart contracts in the context of transparent implementation of projects of the circular economy [24];

– *S6* – Integrated + Governance Max: maximal integration with full LegalTech orchestration (including mechanisms and instruments of e-tender/e-contract/smart [25]), high participation of social enterprises, strict UXO → Remediation – the hard constraint.

3. Reasoned choice of the visual-analytical package in the composition: dendrograms (clustering of territories), PCP (*E**, *S**, *P**, *G** and utility *U*), Butterfly Chart (for the visualization of the progress of achieving goals, as well as the visualization of gaps).

4. GIS analysis: geography of placement of social enterprises and the territorial analysis of consumers in remediation, analysis of transport accessibility, analysis of territories of agricultural designation, objects of water and energy supply, and UXO zones (territories with unexploded ordnance) → prioritization of locations of remediation and the contours of "UXO → Remediation" [26, 27].

Approbation of the digital model was conducted as an ex-ante pilot for Kharkiv region (horizon H2-2026 → 2030), with the starting base 2026 H2 and target normalization of KPI by 2030. The S/E/I/C/G data were collected in a Data Mesh with quality verification (DQ-SLA), robust normalization (robust z-score, taking polarity into account), and then subsequent aggregation into branch indices *E**, *S**, *P**, *G**. The top-level weights α, β, γ, Δ were determined by us through AHP/ANP and were calibrated by learning-to-rank. Forecasts of the target indicators *Y* were built by a stack of GBDT + LSTM + GAM with conformal calibration (95% PI) and XAI (SHAP/ICE), and the causal part was evaluated by a DiD design with PSM selection of control locations (pre/post), which made it possible to separate the effect of the portfolio of projects from background trends. The scenarios (*S1*–*S6*) were compared in MCDA; further a multi-period MILP/ε-constraint optimization of the portfolio *x** was performed with hard precedence UXO → Remediation, budget/calendar constraints, fairness quotas, and CVaR constraints by deadlines/cost. The level of probability and uncertainty was evaluated with the help of the Monte Carlo method (N = 5,000). Spatial effects were analyzed in GIS by the coverage function $Z(x, y) = 1 - \prod(1 - \phi p\ up\ xp)$ taking into account cost-distance and barriers. The prioritization of territories for clearance from military contamination and subsequent remediation was refined by the dendrogram with the help of cluster-dependent weights. For governance, LegalTech orchestration was applied: rules of Compliance-as-Code, e-tender/e-contract, smart payments pay-for-impact and LT risk-event scoring; KPI were confirmed by "oracles" (registries/GIS/IoT), and execution events were recorded in WORM logs. The visual-analytical package included PCP (profiles *E**, *S**, *P**, *G**, *U*, Butterfly Chart (progress/gap to the goals of 2030), and Dendrogram (clustering of territories).

As a result, the approbation of the digital model carried out showed that with the horizon H2-2026 → 2030 the portfolio x^* ensures substantial progress on ecology and manageability of projects: remediation of soil and water resources approaches the established standards ($E1\ \Delta \approx -29$ p.p.; $E2\ \Delta \approx -16$ p.p., DiD are significant), UXO-cleared grows by ≈ +37 p.p. for the portfolio, and risk (*G*4) decreases to the indicator 0.17 with the simultaneous reduction of lead-time from 48 to 26 days. The social results are confirmed: increase of the level of employment + ≈ 680 FTE (with a focus on vulnerable groups of the population, *author's note*), participation of the local community in socially and ecologically significant projects +0.21; social assistance/training/rehabilitation ≈ 1200 participants. The economic block is stable: median IRR ≈ 11.4%, SROI ≈ 2.3, at the same time local procurements grew from 0.34 to 0.55 (DiD ≈ +0.19), but remain among the key zones of fine-tuning along with the bio-index (*E*5). Air cleaning (*E*3) demonstrates a positive trend ($\Delta \approx -8$ p.p.), however statistical significance is on the verge ($p \approx 0.08$) due to weather volatility – extended observation and additional analysis of weather regressors are required. Integrally $U(x^*) = 0.682$ at $(\alpha, \beta, \gamma, \Delta) = (0.35, 0.25, 0.25, 0.15)$; robustness is confirmed (IQR [0.666; 0.691], rank stability amounts to ~92%), the indicators of the level of risks are within the norm ($CVaR_{95}$ deadlines 12.4%, CAPEX 9.2%). The spatial effect increased: average $Z(x, y)$ from 0.18 to 0.47, zone $Z \geq 0.6 \sim 1{,}850$ km^2, logistics improved (cost-distance −13%). LegalTech orchestration ensures e-tender ≈ 93%, smart-coverage ≈ 68%, 17 out of 19 anomalies were identified and successfully settled; violations of SLA > 30 days – 0.

The data of the **Table 9.4** presented below confirm the fact that the pilot for Kharkiv region passed key checks of data quality, forecast accuracy, and managerial effects. Completeness of critical fields (DQ) amounted to 96.8% with a target ≥ 95% – the source data are sufficient for reliable computations. Forecast accuracy (MAPE) for targets *Y* fit into the threshold ≤ 15% (range 11.9–16.2%); the only exception – SROI with 16.2% (on the edge of admissible with reservations, *author's note*). Calibration of the risk model (ECE = 0.028) corresponds to the requirement ≤ 0.03, that is, the probabilistic estimates of risk are not systematically overestimated/underestimated, which is acceptable. Reduction of managerial risk (*G*4) reached ≈ −47% with a target −30%, and the share of achievements of MPC in the cores – ≈ 82% (target ≥ 75%), which confirms ecological effectiveness. The principle of fairness (fairness) is observed (at least one project in each cluster annually), and lead-time decreased by approximately −46% with a target −25%, which reflects the effect of LegalTech orchestration. Taken together, the criteria indicate the conformity of the approbated digital model to the acceptance conditions and its readiness for scaling; at the same time, it is expedient to strengthen

the SROI block (expansion of the sample, quantile loss, refinement of external effects is recommended).

Table 9.4 Validation and criteria of the overall assessment of the approbation of the digital model

Criterion	Target	Fact	Status
DQ completeness of critical fields	≥ 95%	96.8%	✓
MAPE for *Y*	≤ 15%	11.9–16.2%*	(SROI 16.2%)
ECE (risk calibration)	≤ 0.03	0.028	✓
Reduction of G4	−30%	≈ −47%	✓
MPC in cores (to Tmax)	≥ 75%	≈ 82%	✓
Fairness (≥ 1 project/cluster/year)	Yes	Yes	✓
Lead-time (median)	−25%	≈ −46%	✓

*Note: * for SROI MAPE = 16.2% – acceptable with a note: high dispersion of external effects. In the plan – to expand the training sample and apply quantile loss*

The visualization of the approbation results of the digital model using the example of Kharkiv region is presented in the figures below (**Fig. 9.2–9.4**).

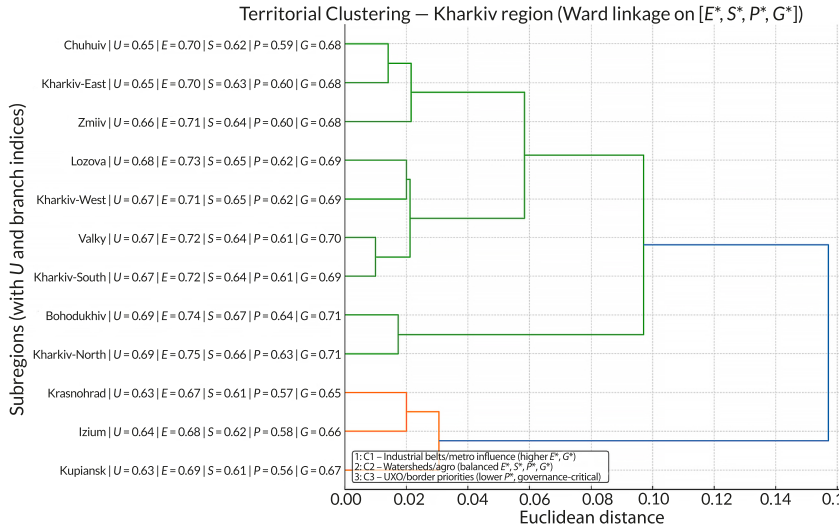

Fig. 9.2 Dendrogram: subregions of Kharkiv region (by *E**, *S**, *P**, *G**)

Let's note that the presented dendrogram performs hierarchical clustering of the subregions of Kharkiv region by the vector of normalized indices [E^*, S^*, P^*, G^*] (Ward linkage; Euclidean distance). On each segment of the dendrogram the integral utility U and the branch values are indicated: in the "metropolitan" zones (Kharkiv-North/South/East/West, Bohodukhiv) $U \approx 0.67–0.69$ with comparatively high E^* and G^* – this is cluster $C1$. $C2$ (Lozova, Valky, Zmiiv) – balanced agro/catchment territories with $U \approx 0.66–0.68$. $C3$ (Izium, Kupiansk, Krasnohrad, Chuhuiv) – UXO/border profile with lower P^* ($\approx 0.57–0.59$) and $U \approx 0.63–0.65$, which singles them out as a zone of increased managerial attention. The greatest "height of merging" between $C1$ and $C3$ indicates the greatest structural distinctness and the necessity of a differentiated policy.

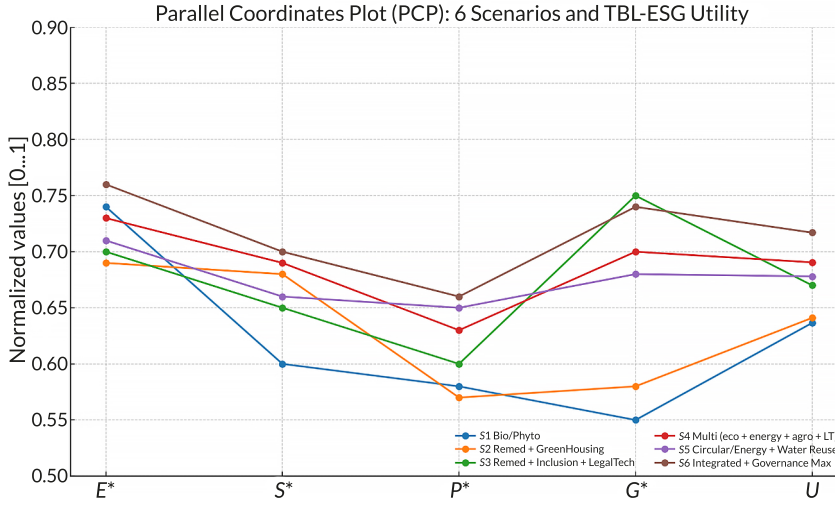

Fig. 9.3 Parallel coordinates plot (PCP): 6 scenarios and TBL-ESG utility

The Parallel Coordinates Plot presented above visualizes the profiles of six scenarios ($S1–S6$) by the normalized branch indices E^*, S^*, P^*, G^* (scale 0...1) and the final utility U. As can be seen from the data of the chart, the leader is scenario $S6$ Integrated + Governance Max: $E^* = 0.76$; $S^* = 0.70$; $P^* = 0.66$; $G^* = 0.74$, which gives the highest utility indicator $U \approx 0.72$. Scenario $S3$ Remed + Inclusion + LegalTech stands out with a maximal $G^* \approx 0.75$ with a moderate $P^* \approx 0.60$, providing at the same time a quite high, but not the best, utility indicator U. Scenario $S4$ Multi is rather balanced ($E^* \approx 0.73$; $S^* \approx 0.69$; $P^* \approx 0.63$; $G^* \approx 0.70$; $U \approx 0.69$). Scenario $S5$ Circular/

Energy is quite close by the integral utility result ($U \approx 0.68$). Scenario *S*1 Bio/Phyto is strong in environmental effectiveness ($E^* \approx 0.74$), but weaker in S^*, P^*, and G^* ($\approx 0.60/0.58/0.55$) – $U \approx 0.64$; scenario *S*2 Remed + GreenHousing is constrained by low $P^* \approx 0.57$ and $G^* \approx 0.58$ with a good level of indicators $S^* \approx 0.68$ – $U \approx 0.64$. The intersections of the lines on the axes show trade-offs: strengthening Governance (G^*) and the overall balance of metrics raise the *U* indicator even at an average level of P^*.

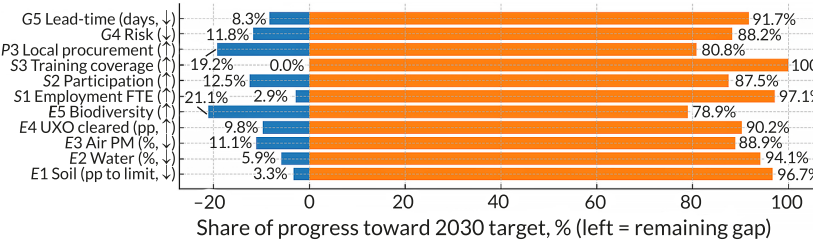

Fig. 9.4 Butterfly chart: progress to the goals (2026 H2 → 2030, Kharkiv region)

The Butterfly Chart presented above reflects for each KPI the share of progress toward the goals of 2030 (right/orange wing) and the remaining gap (left/blue wing) from the baseline level 2026 H2 for Kharkiv region. The strongest positions are observed for the scenarios: *S*3 Training – 100%, *S*1 Employment – 97.1%, as well as ecology *E*1 Soil – 96.7% and *E*2 Water resources – 94.1%. As is seen, the managerial indicator *G*5 Lead-time is close to the goal – 91.7%. The middle echelon of indicators covers the following blocks: *E*4 UXO cleared – 90.2%, *E*3 Air (PM) – 88.9%, *G*4 Risk – 88.2%, *S*2 Participation of SE in projects of remediation and revitalization – 87.5%. The main lags are observed in: *E*5 Bioindex (78.9%, the gap amounts to 21.1%) and *P*3 Local procurements (80.8%, the gap amounts to 19.2%), which points to priority zones of fine-tuning of the policy of resource provision of the region.

9.5 Conclusion

The research result is the confirmation of the thesis that social entrepreneurship acts as a driver of green remediation and revitalization: through the involvement of the local community in the process of restoration of the affected territories, employment of vulnerable population groups, assistance and support to the affected and temporarily displaced persons, localization of supply chains and transparency of the implementation of projects. Moreover, it is capable of turning the goals of sustainable

development into contractable and scalable projects. The theoretical-methodological basis of the research rests on the bundle TBL → ESG (for the purposes of evaluation and operationalization), DSS (for the purposes of selection and optimization of managerial decisions) and LegalTech (for the purposes of transparent legal execution), united in a single architecture with Data Mesh, GIS, multi-criteria analysis (MCDA) and robust portfolio optimization (including CVaR). The scientific novelty consists in the orchestration of TBL–ESG, DSS, LegalTech and GIS in one end-to-end contour "data → analytics → decision → contract → KPI payments → confirmed effect", which ensures manageability and verifiability of impact. Approbation on the example of Kharkiv region (horizon of forecast modeling: H2-2026 → 2030) showed the attainability of the target trajectories, namely: high levels of progress in increasing the level of employment and training, substantial convergence of the indicators of cleaning of soil and water resources in accordance with the standards, growth of the share of UXO-cleared and noticeable improvement of the indicators of manageability (in particular, reduction of the level of risk, as well as acceleration of the procedures of remediation and revitalization). The visual-analytical package (Dendrogram, PCP, Butterfly Chart) demonstrated transparent profiles of scenarios and differences of territories subject to clearance from military contamination and subsequent remediation, which made it possible to adapt the weights and thresholds by clusters and to reduce the "bottlenecks" of implementation. The practical value of the model is in ensuring end-to-end managerial visibility for the authorities, the local community, investors and donors, in the reduction of transaction costs through e-tender/e-contract and pay-for-impact smart payments, as well as in the creation of predictable conditions for the financing of projects of the development of social entrepreneurship.

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