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Computational Science and Its Applications – ICCSA 2020

20th International Conference
Cagliari, Italy, July 1–4, 2020
Proceedings, Part III

3 **Part III**

ICCSA 2020

INTERNATIONAL CONFERENCE ON COMPUTATIONAL SCIENCE AND ITS APPLICATIONS

Springer

Lecture Notes in Computer Science 12251

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Preface

These seven volumes (LNCS volumes 12249–12255) consist of the peer-reviewed papers from the International Conference on Computational Science and Its Applications (ICCSA 2020) which took place from July 1–4, 2020. Initially the conference was planned to be held in Cagliari, Italy, in collaboration with the University of Cagliari, but due to the COVID-19 pandemic it was organized as an online event.

ICCSA 2020 was a successful event in the conference series, previously held in Saint Petersburg, Russia (2019), Melbourne, Australia (2018), Trieste, Italy (2017), Beijing, China (2016), Banff, Canada (2015), Guimaraes, Portugal (2014), Ho Chi Minh City, Vietnam (2013), Salvador, Brazil (2012), Santander, Spain (2011), Fukuoka, Japan (2010), Suwon, South Korea (2009), Perugia, Italy (2008), Kuala Lumpur, Malaysia (2007), Glasgow, UK (2006), Singapore (2005), Assisi, Italy (2004), Montreal, Canada (2003), and (as ICCS) Amsterdam, The Netherlands (2002) and San Francisco, USA (2001).

Computational science is the main pillar of most of the present research, industrial and commercial applications, and plays a unique role in exploiting ICT innovative technologies. The ICCSA conference series has provided a venue for researchers and industry practitioners to discuss new ideas, to share complex problems and their solutions, and to shape new trends in computational science.

Apart from the general track, ICCSA 2020 also included 52 workshops in various areas of computational science, ranging from computational science technologies to specific areas of computational science, such as software engineering, security, machine learning and artificial intelligence, blockchain technologies, and of applications in many fields. We accepted 498 papers, distributed among 6 conference main tracks, which included 52 in workshops and 32 short papers. We would like to express our appreciation to the workshops chairs and co-chairs for their hard work and dedication.

The success of the ICCSA conference series in general, and of ICCSA 2020 in particular, vitaly depends on the support from many people: authors, presenters, participants, keynote speakers, workshop chairs, session chairs, Organizing Committee members, student volunteers, Program Committee members, Advisory Committee members, international liaison chairs, reviewers, and others in various roles. We take this opportunity to wholeheartedly thank them all.

We also wish to thank our publisher, Springer, for their acceptance to publish the proceedings, for sponsoring part of the Best Papers Awards, and for their kind assistance and cooperation during the editing process.

We cordially invite you to visit the ICCSA website http://www.iccsa.org where you can find all the relevant information about this interesting and exciting event.

July 2020

Osvaldo Gervasi
Beniamino Murgante
Sanjay Misra

Welcome to the Online Conference

The COVID-19 pandemic disrupted our plans for ICCSA 2020, as was the case for the scientific community around the world. Hence, we had to promptly regroup and rush to set in place the organization and the underlying infrastructure of the online event.

We chose to build the technological infrastructure using only open source software. In particular, we used Jitsi (`jitsi.org`) for the videoconferencing, Riot (`riot.im`) together with Matrix (`matrix.org`) for chat and asynchronous communication, and Jibri (`github.com/jitsi/jibri`) for live streaming sessions on YouTube.

Six Jitsi servers were set up, one for each parallel session. The participants of the sessions were helped and assisted by eight volunteer students (from the Universities of Cagliari, Florence, Perugia, and Bari), who assured technical support and smooth running of the conference proceedings.

The implementation of the software infrastructure and the technical coordination of the volunteers was carried out by Damiano Perri and Marco Simonetti.

Our warmest thanks go to all the volunteering students, to the technical coordinators, and to the development communities of Jitsi, Jibri, Riot, and Matrix, who made their terrific platforms available as open source software.

Our heartfelt thanks go to the keynote speakers: Yaneer Bar-Yam, Cecilia Ceccarelli, and Vincenzo Piuri and to the guests of the closing keynote panel: Mike Batty, Denise Pumain, and Alexis Tsoukiàs.

A big thank you goes to all the 454 speakers, many of whom showed an enormous collaborative spirit, sometimes participating and presenting in almost prohibitive times of the day, given that the participants of this year's conference come from 52 countries scattered over many time zones of the globe.

Finally, we would like to thank Google for letting us livestream all the events via YouTube. In addition to lightening the load of our Jitsi servers, that will allow us to keep memory and to be able to review the most exciting moments of the conference.

We all hope to meet in our beautiful Cagliari next year, safe from COVID-19, and finally free to meet in person and enjoy the beauty of the ICCSA community in the enchanting Sardinia.

July 2020   Ivan Blečić
                                                                     Chiara Garau

Organization

ICCSA 2020 was organized by the University of Cagliari (Italy), University of Perugia (Italy), University of Basilicata (Italy), Monash University (Australia), Kyushu Sangyo University (Japan), and University of Minho (Portugal).

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(GEOG-AND-MOD 2020)**

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A Model to Support the Investment Decisions Through Social Impact Bonds as Effective Financial Instruments for the Enhancement of Social Welfare Policies

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Abstract. Despite the widespread opinion that the traditional finance is exclusively interested in the monetary return, in the last ten years this sector has been affected by a contamination of the public principles related to the social impacts. The global development and the spread of "win-win" financial instruments such as the Social Impact Bonds (SIBs) outlines a growing interest in making an investment that aims at generating benefits for all the subjects involved, always guaranteeing a monetary return to the private investor. The complexity of identifying the social impact sectors to be preferred, in a context characterized by different social needs, represents a critical issue in the SIBs investment. This research defines a model that can constitute a decision support tool for the public and private subjects in the preliminary phases concerning the resource allocation for a social program. The proposed algorithm allows to define a temporal priority of the social impact sectors that are simultaneously able to maximize the conveniences for all the subjects involved. Through the model, the public and private subjects will be able to determine the best allocation of financial resources according to the real social needs, contributing to an effective spread of SIBs both in Italy and abroad.

Keywords: Social impact bond · Social investments · Public-private partnership · Operational research · Decision support tools

1 Introduction

In the context of Sustainable and Responsible Investment (SRI), a sustainable finance approach born after the 2007 financial crisis, named the Social Impact Investments (SII), represents a new generation of impact investing. Defined as a wide range of investments based on the assumption that private capital can intentionally contribute to positive social impacts and, at the same time, financial returns, the SII stand out for the

proactive intention with which the investor pursues the social purpose, together with the financial return, differently from the profit-only approach of traditional finance tools. In particular, the SII consist of a transaction between a private investor and a social enterprise, aimed at beneficiaries in difficulty. Therefore, the characteristics of the SII can be summarized as follow:

- *intentionality*, that is, the willing of the investor to generate a positive impact through the investment;
- *expectations of financial return*s, differentiating themselves from donations for which investors do not expect a monetary return;
- *flexibility of the expected rate of return*, which may be below the average market level or align with the average or higher yield;
- *measurability of the impact* generated through assessment techniques that can translate impacts into monetary terms;
- *breadth of investment instruments*, through the use of different asset classes, ranging from debt to pure equity, with different yield and risk profiles.

On the demand side, the SII promote the growth process of social enterprises, the ability to propose suitable responses to the complexity of new social needs and, at the same time, an economic and financial feasibility of intervention models. On the supply side, the SII stimulate the growth of a new generation of responsible investors, helping to spread the outcome-oriented approach that forms the theoretical basis on which the different social investment instruments are based.

The social investors, called *Impact First*, are solidarity organizations whose priority is to achieve the established social or environmental purpose, to the detriment of financial returns (e.g. charitable organizations, venture capital and venture philanthropy funds). It often happens that they find themselves working together with *Financial First* investors, who are influenced mainly by the financial return they can obtain, constituting the so called *Layered Structures*, which allows the Financial First to obtain the expected returns at market rates and Impact First to be able to make the most of their investment capital, thus achieving a more significant impact than that obtained if they had independently operated. The most common motivations for private investors to carry out impact investing concern *i)* the willingness of organizations to be responsible investors (85%), *ii)* the dedication to their missions (84%), *iii)* the search for efficient modalities to achieve their impact investment objectives (71%). A further important factor for the impact investing is represented by the respect of the United Nations sustainable development goals set in the 2030 Agenda for Sustainable Development or in the climate agreement held in Paris in 2015 [7].

There is ample evidence that the growth of the social sector stimulates the growth of the economic sector; social development closely linked to the government's practices for public welfare whose austerity policies, caused by the 2007 financial crisis, have imposed a constraint on the budget of public finances [8]. The constraint on public expenditure on welfare is probably a powerful driver of the diffusion of the SII tools, therefore, the public-private partnership acquires an important role [1–3, 17]. The involvement of private financial resources for public purposes has shown its effectiveness in numerous initiatives [19, 20, 22]. In doing so, for the financial private world the welfare deficit appears as a new market, while for the policy maker's point of view

the public-private partnership is a way to address the lack of public money, in order to provide the necessary resources for supporting the weaker of the community.

The Governments have been keen to support alternative service delivery as a way to shrink public sector costs and responsibilities [5] and they have begun experimenting with tools to encourage alternative service funding through innovations such as social impact bonds (SIBs). The SIBs are a financial tool used to encourage private, philanthropic or public investors to provide upfront capital to support project-oriented service delivery by private sector social investors.

2 Aim

Taking into account the framework outlined, in this research a decision support model that allows to define investment priorities among different social impact sectors has been developed, by borrowing the principles and theory of Operational Research. The model adopts the branch and bound algorithm for identifying the priority investment alternatives in the different social impact sectors considered. Each investment alternative is distinguished by several weighted criteria that define its main characteristics and represent the aspects that the social investor and the Public Administration should take into account for the adoption of the SIBs.

The model will serve the social investor and the Public Administration to carry out a screening of the types of social impact sectors in which to invest primarily for the activation of a social program using the Social Impact Bonds. The adoption of the proposed model must provide a simple and immediate support to the decisions to be taken in the preliminary phase of identifying the social issues to be addressed. The model should also support decisions to be taken for both small scale and large scale social issues.

The rest of the paper is organized as follows. In Sect. 3 the current diffusion of the SIBs has been outlined. In Sect. 4 the algorithm of the model proposed has been defined: the variables, the objective function and the constraints to be considered for the implementation of the model have been specified. In Sect. 5 the potentialities and the limitations of the proposed model have been discussed.

3 The Social Impact Bonds

Starting from 2010, the empirical literature that focuses on aspects of the SIBs implementation is growing. This consists of reports commissioned by governments and consultancies seeking to highlight the practical advantages and disadvantages to be learned from SIBs adoption [4, 18, 21]. These reports are almost exclusively qualitative and highlight many of the practical challenges involved in initiating SIBs such as high transaction costs, complexity in contractual negotiations, uncertainty relating to the risk and the return deriving from the (entrepreneurial and managerial) capacity of social enterprises to provide services related to the results of the program, difficulty in evaluating and quantifying the expected results, limitation of the budgets that can be spent by the local public administration funds. A part of this literature focuses instead

on the motivations that could lead the actors to decide not to pursue a SIB, mainly identified in a lack of sharing of the interests of the subjects involved [6, 13, 16].

The SIB's strategic ambiguity has advantages for both their proponents and critics, and they are lauded for their potential:

- to foster innovation [10];
- to "scale-up" evidence-based programs [12];
- to enable flexible and personalized services tailored to service users [9];
- to improve productivity and value for money or promote more measurement and accountability both for privates and public sector [11].

Thus, there are interesting questions emerging about whether the SIBs challenge or reinforce existing governance logics for actors, institutions and networks involved in experimenting with this new commissioning tool. Developing a SIB at the local level frequently involves the development of new relationships between the actors and the subjects that provide services in the social sector in response to existing and emerging policy problems. This, in turn, may strain (or conversely, it may strengthen) existing relationships and system governance.

Since the launch of the first SIB in 2010 in England, there has been a significant spread of the phenomenon with 137 cases implemented worldwide for a total number of beneficiaries amounting to 1,711,130 (Table 1).

Table 1. Number of SIBs implemented by geographical area, capital raised and number of beneficiaries (source: own elaboration based on https://sibdatabase.socialfinance.org.uk/).

	Number of launched sibs	Capital raised	Number of beneficiaries
United Kingdom	47	£ 44,7 M	54,233
United States	26	$ 219 M	659,482
Australia	10	AUD 57,2 M	8,280
Netherlands	11	€ 11,5 M	2,850
Canada	4	C$ 4,30 M	7,201
France	5	€ 1,95 M	14,030
Israel	3	€ 22,4 M	4,050
Portugal	4	€ 1,72 M	611
Japan	3	–	–
India	3	$ 14,8 M	918,000
South Africa	1	$ 0.540 M	1,000
Finland	2	€ 10,7 M	4,300
Colombia	1	$ 0.750 M	511
Belgium	2	€ 0.230 M	450
Uganda	1	$ 2,40 M	13,830
Cameroon	1	$ 250 M	18,000
Germany	3	€ 0.300 M	148
New Zeland	2	NZ$ 7,50 M	2,700
South Korea	2	₩ 110 M	100

(*continued*)

Table 1. (*continued*)

	Number of launched sibs	Capital raised	Number of beneficiaries
Sweden	1	SEK 10,0 M	60
Switzerland	1	CHF 0.720 M	120
Argentina	1	AR$ 40,0 M	1,000
Congo	1	$ 27,0 M	0
Austria	1	€ 0.800 M	75
Peru	1	$ 0.110 M	99
Total	–	–	**1,711,130**

What is shown in Table 1 highlights the adoption of SIBs in different geographical areas of the world whose entire, characterized by a series of social needs expressed by local populations, allows to define the extent of the impact generated and consequently the system of needs expressed by populations. Generally, there are seven main macro-categories that represent the social sectors of interest of SIBs: *i)* Child and family welfare; *ii)* Criminal Justice; *iii)* Education; *iv)* Environment; *v)* Health; *vi)* Homelessness; *vii)* Workforce development. The typology of needs expressed, and the importance attributed to a certain sector through the social programs launched by local governments is highlighted by the distribution of the SIBs in each country according to the respective social impact sector (Table 2).

Table 2. Number of SIBs implemented in each social impact sector (own elaboration based on data from: https://sibdatabase.socialfinance.org.uk/)

Country	Social issue						
	Child and family welfare	Criminal justice	Education	Environment	Health	Homelessness	Workforce development
United Kingdom	6	1	1	–	8	16	15
United States	6	8	2	1	3	4	2
Australia	4	1	–	–	1	3	1
Netherlands	–	1	–	1	1	–	8
Canada	1	–	1	–	1	–	1
France	–	–	1	–	–	–	4
Israel	–	–	1	–	1	–	1
Portugal	1	–	1	–	–	–	2
Japan	–	–	–	–	3	–	–
India	–	–	2	–	1	–	–
South Africa	1	–	–	–	–	–	–

Table 2. (*continued*)

Country	Social issue						
	Child and family welfare	Criminal justice	Education	Environment	Health	Homelessness	Workforce development
Finland	–	–	–	–	–	–	2
Colombia	–	–	–	–	–	–	1
Belgium	–	–	–	–	–	–	2
Uganda	–	–	–	1	–	–	–
Cameroon	–	–	–	–	1	–	–
Germany	–	–	2	–	–	–	1
New Zeland	–	1	–	–	1	–	–
South Korea	–	–	1	–	–	–	1
Sweden	–	–	1	–	–	–	–
Switzerland	–	–	–	–	–	–	1
Argentina	–	–	–	–	–	–	1
Congo	–	–	–	–	1	–	–
Austria	1	–	–	–	–	–	–
Peru	–	–	–	–	–	–	1
Subtotals	**20**	**12**	**13**	**3**	**22**	**23**	**44**

   The data show a high number of interventions (44) in the Workforce development sector for almost all countries, whereas it is evident that the number of Environment initiatives is limited (3). The interventions included in the social environmental impact sector are not very frequent because they are considered complex due to the vast territorial scale in which they are carried out and the multiple aspects and subjects involved (such as the construction of a water and sewage system for the most poor cities or reforestation projects). This condition is also confirmed by the number of funds that decide to invest pursuing an environmental focus or a social focus. From the data present in the ImpactBase database (source: www.impactbase.org/) it appears in fact that, until 2017, there is a greater number of funds involved in social initiatives rather than environmental ones, also due to the target return respectively obtainable (Fig. 1).

**FUNDS INVOLVED IN THE IMPACT INVESTING
SECTOR**

■ Social focus   ■ Environmental focus
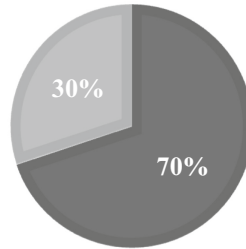
Fig. 1. Percentage of funds involved in initiatives with a social and environmental focus (source: www.impactbase.org/)

Moreover, England holds the record for the largest number of SIBs implemented (47), especially in the Homelessness (16) and Workforce development sectors (15), evidence in accordance with the reasons that led to the birth of SIBs. Except for the United States, Netherlands and Australia where the most widespread SIBs concern the sectors of Workforce Development, Criminal Justice and Child and family welfare, in the remaining geographical contexts the SIB have not had a development comparable to the previous ones. The subdivision of the projects implemented through the adoption of SIBs into macro categories of intervention is necessary to understand the relevance of the social issues felt by local governments, which as a result, carry out appropriate intervention.

4   The Model

The proposed model is based on the principles and theory of the Operational Research, a methodology of considerable flexibility and efficiency that is frequently used in the field of project evaluation and feasibility territorial investments [19, 20] for the resolution of a goal programming problem. The generic problem of goal programming can be traced back to the determination of the excellent use of scarce resources usable in alternative modalities. For the specific field of interest, the goal programming problem is characterized as follows:

- resources available in limited quantity are represented by the different social impact sectors;
- the alternative uses correspond the various weighted criteria, identifying the important aspects considered by the subjects involved (social investors, Public Administrations etc.);
- the constraints that translate into mathematical terms the temporal priority of social impact sectors taking into account the weighted criteria identified;

- the objective functions that reflect the goals pursued by the subjects involved in the social initiative, in terms of maximization (or minimization) of the respective expected outputs.

In this research, the proposed model applies the branch and bound algorithm [14, 15]. Based on a partition and branching mechanism of the sets of solutions and the calculation of a limit value of the objective function, the branch and bound algorithm proceeds for a partial exploration of the feasible solutions. In this case, clarified that, increasing the number of the n social impact sectors and the number of the m weighted criteria, the combinations to be examined become so numerous that the enumeration of the total number of solutions could be impossible, the branch and bound algorithm decomposes the domain solutions into subsets whose intersection is null and whose union coincides with the starter set. The best combination is sought in the subsets obtained through a strategy that aims to verify whether the partition should be further subdivided or may be excluded from further analysis.

The implementation of the branch and bound algorithm provides the introduction of a binary variable k_i, associated to the i-th ($i = 1, \ldots, n$) social impact sectors. Therefore, k_i represents the branching variable, which assumes a value "1" if the i-th social impact sector satisfies the objective function, and a value "0" otherwise.

With the aim of defining a temporal priority order of the investment sectors according to the different weighted criteria, it is evident that the first selection of the i-th investment sector - which is therefore the first in order of realization - excludes the other $n-1$ sectors. This will be followed by $n - 2$ elaborations, aimed at identifying, in each of them, the i-th investment sector which, in terms of capacity to satisfy the intended objective function, follows that generated in the previous processing. Therefore, the first constraint of the model can be defined through Eq. (1), in order to ensure that the branching variable k_i takes the value "1" for only one of the j social impact sectors, with j = n, n − 1, …, 2 repeating this process:

$$\sum_{i=1}^{j} k_i = 1 \qquad j = n, n-1, \ldots, 2 \tag{1}$$

The second constraint concerns the definition, for each l-th selection criterion, of the capacity (G_l) of the investment sectors to satisfy the considered constraint. By indicating with v_{il} the score of the i-th investment sector in satisfying the l-th selection criterion, the second constraint of the model is expressed by Eq. (2):

$$\sum_{i=1}^{j} k_i \cdot v_{il} = G_l \begin{cases} j = n, n-1, \ldots, 2 \\ l = 1, \ldots, m \end{cases} \tag{2}$$

The objective function of the proposed model pursues the maximization (or the minimization) of the outputs expected by the subjects involved in the process, i.e. the sum of the capacities (G_l) of the social impact sectors to satisfy the weighted criteria considered. Taking into account that the weight attributed to each criterion of the social impact sectors could be different, thus indicating with p_l the weight attributed to the l-th selection criterion, the objective function will be expressed by Eq. (3):

$$\max/\min\left(\sum_{l=1}^{m} p_l \cdot G_l\right) \tag{3}$$

In Table 3 the algorithm of the proposed model has been reported, whereas in Table 4 the meaning of each term of the algorithm has been explained.

Table 3. Algorithm of the proposed model

Variable	k_i
Objective function	Max/min $(\sum_{l=1}^{m} p_l \cdot G_l)$
Constraints	$\sum_{i=1}^{j} k_i = 1 \quad j = n, n-1, \ldots, 2$
	$\sum_{i=1}^{j} k_i \cdot v_{il} = G_l \begin{cases} j = n, n-1, \ldots, 2 \\ l = 1, \ldots, m \end{cases}$

Table 4. Variable and exogenous parameters of the proposed model

k_i	Binary variable associated to the i-th social impact sectors
v_{il}	Score attributed to the i-th investment sector in meeting the l-th criterion
G_l	Capacity of all social impact sectors to suit the l-th criterion
p_l	Weight attributed to the l-th criterion

In the present research the branch and bound algorithm will thus be able to provide the outputs, in order of temporal priority, of social impact sectors as outputs based on the values assumed by the return function of the model. In this way, the public subject and the social investor will be able to determine the best allocation of financial resources according to the real social needs and the expected financial returns.

5 Conclusions

In recent years, traditional financial instruments have been weak in investments aimed at solving complex social problems. New innovative models have also emerged in the SRI field to respond to the growing social and environmental challenges. The SII represent one of the most interesting SRI fields due to the willing to generate value in terms of both a measurable positive social impact and a financial return. The development and global spread of "win – win" financial instruments such as SIB are proof of a growing interest in the realization of an investment that aims at generating benefits for all the subjects involved. Taking into account the frequent low effectiveness of numerous social welfare policies and the reduction of financial resources available to the public sector, the investments in SIB can constitute a useful tool for governments. Private sector investments in SIB would not only be able to help public social

programs, but they could also provide such programs to a scale that would include a larger amount of beneficiaries.

However, the spread and the development of SIBs did not occur with the same force in all the countries. The complexity connected to the identification of the social impact sector in which investing in a territorial context characterized by a plurality of different social needs is one of the critical points highlighted in the literature for the development of the SIBs. The proposed operational research model has been defined to overcome this critical issue and to contribute to the spread of SIBs both in Italy and abroad.

Future developments of the present research may concern the verification of the validity and the reliability of the proposed model through the application to a real situation that can characterize, for example, a municipal area. Moreover, the definition of specific criteria that allow to represent the variety of aspects that the decision makers, according to their objectives and roles, evaluate for the activation of a social program, will allow to highlight how the process of identifying the social impact sector in which investing is closely related to a plurality of factors and requires an accurate assessment.

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