Social movements, relative deprivation and cellular automata

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Abstract: In the last few years, we have seen the birth of social movements that, in some cases, have resulted in outbreaks of violence around the world. Experts have suggested the theory of relative deprivation to describe the origin of these movements. This research proposes a relative deprivation index (RDI) to measure the potential for current social satisfaction/discontent. Additionally, a cellular automaton is employed to evaluate how the RDI turns into future satisfied, indifferent, and dissatisfied citizens. The proposed theory is applied to a practical case, and a software tool for its solution is presented.

Subjects: Public Policy; Budgetary & Economic Policy; Research Methods - Soc; Policy

Keywords: Social Movements; Relative Deprivation; Cellular Automata; Relative Deprivation Index

1. Social movements: definition and evolution

In the last few years, we have witnessed the birth of social movements around the world that, in some cases, have resulted in outbreaks of violence. Social movements, defined as organized groups that act consciously to promote or resist change through collective action (Goldberg, 1991), should not be confused with social organizations, which are formally constituted and structured. Then, by definition, a social movement is understood outside of any mainstream position and allows the expression of excluded groups (Greenberg & Page, 1993).

As social movements have multiple motivations, their classification is problematic. However, some experts have classified them according to two variables: the number of people they want to reach and the depth of the changes they seek to generate (Aberle et al., 1950), (Blumer, 1974). According to this, there are four types of social movements (Figure 1)

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English: This paper analysed the relation between public investment and the satisfaction/discontent level of citizens. Thereby the study proposes a new relative deprivation index (RDI) and the use of a quantitative model to measure the potential for current and future satisfied, indifferent, and dissatisfied populations. In addition, a case study based on 7 Chilean municipalities, served to demonstrate how the application of modelling could be used to predict relationships between public investment levels and population dissatisfaction rates.

Spanish: Esta investigación analizó la relación entre la inversión pública y el nivel de satisfacción/descontento de los ciudadanos. De esta manera, el estudio propone un nuevo índice de privación percibida (IPP) y el uso de un modelo cuantitativo para medir el potencial de ciudadanos satisfechos, indiferentes e insatisfechos (actuales y futuros). Además, mediante un caso práctico basado en 7 municipios chilenos, se demuestra cómo la aplicación de modelos podría usarse para predecir la relación entre los niveles de inversión pública y las tasas de insatisfacción de la población.
(a) Change movements, which seek to generate a specific change in society (e.g., environmental movements). These movements generally aim to work with the current system to induce changes aligned with their goals and values.

(b) Revolutionary movements, which pursue radical change in the society as a whole. These movements do not want to work with the current system; on the contrary, they seek to replace existing institutions with new ones that reflect their beliefs. These movements can range from simple utopians to groups that use violence to achieve their goals (Masotti & Bowen, 1970); the latter can include terrorist activity (White, 2003).

(c) Redemptive movements, which seek radical changes at the individual level, generally based on religious or spiritual understanding.

(d) Alternative movements, which aim to achieve specific, relatively small changes at the individual level. Examples of these movements can be found in trends such as meditation and veganism, and in general, those oriented to self-care.

Even if these movements may differ in their motivations, goals, and depth, standard developmental stages can be observed (Tilly, 1973). In the gestation or preliminary stage, there is discontent that grows as people become aware of an ignored problem. This initial stage involves the appearance of leaders within the social group, who encourage participation. In the second stage, the movement’s diagnoses, goals, and ideals are consolidated, thus defining a group’s sense of unity (even without a formal constitution).

In the third stage, bureaucratization, movements establish rules and procedures; generally, paid positions are defined, thus molding the group from a social movement to a social organization. At this stage, members with a greater visionary charge can express their frustration and leave the organization to create a variant or branch of the original.
After bureaucratization, movements can result in the success or failure of their objectives, co-optation of their leaders, repression by larger groups (for example, the government), or integration with other movements (Figure 2). Subsequently, a decay stage is expected.

A typical example of the evolution of a social movement can be found in the free and open source software (FLOSS) community. FLOSS is a structure of traditions and values developed since the 1950s among software developers, which originated at the Massachusetts Institute of Technology (MIT). One of the movements’ main philosophies was the sharing of the source code of programs to avoid repetitive work. With the growing success of personal computers in the 1970s, multiple companies, including the then-new Microsoft, promoted not sharing the code (Gates III, William Henry, 1976).

Faced with the growing bad feeling among the old developers (gestation stage), a former MIT developer, Richard Stallman, responded by announcing his intention to create a completely free operating system (called GNU), which would allow the sharing and modification of its source code (Stallman, 1983b), thus defining the movement born two decades earlier (consolidation stage). The FLOSS social movement then went to the bureaucratization stage in 1985, with the creation of the Foundation for Free Software, and the legal framework in the form of the General Public License (GPL) was announced. With the arrival of the Linux kernel (a subsystem necessary to complete the GNU system; Torvalds, 1991) and the subsequent growth of the Internet, the popularity of free software has grown dramatically, advancing to a position of greater prominence or popularity (especially in server networks). During this stage, derivative movements or branches appeared, such as the Open Source Initiative (Raymond, 2001).

After fulfilling its objective of spreading free software and developing a fully functional and popular system, the organization began to decline. Companies that were originally opposed to the FLOSS concept have developed and/or promoted the use of free software solutions (Microsoft Open Source, 0000) or use these systems for critical functions (Google Open Source, 0000).

Although FLOSS serves to exemplify the evolution of a movement (in this case, of the alternative type), it is essential to delve into the possible reasons for the emergence of such activities, especially those with more radical positions and those that can lead to violence.

2. Social movements’ gestation and the theory of relative deprivation
We have seen that the different types of social movements present stages of gestation, consolidation, bureaucratization, and decline, but what conditions must be met for the birth of a social movement?

Gurr (Gurr, 1970) has identified three factors that can develop social movements: a history of struggles, disputes over the political system’s legitimacy, and the perception of deprivation or lack.

The phenomenon of deprivation is associated with the emergence of violent demonstrations (Crosby, 1976), (Abeles, 1976), (Geschwender, 1968), (Gurr, 1970), protests related to political positions (Abrams, 1990), (Grant & Brown, 1995), (Orum, 1974), riots (Bowen et al., 1968), (Gurr, 1970), negative attitudes toward the police and public institutions (Gaskell, 1990), polarization between citizens, prejudices, discrimination, and ideological conflicts (Appelgryn & Bornman, 1996), , all phenomena recently observed in social movements emerging around the world. Given that this research focuses on these social outbreaks, we will concentrate on the perception of deprivation.

A group experiences relative deprivation when it compares its socio-economic status with that of a similar group and perceives to be at a disadvantage (Birrell, 1972), (Crosby, 1976), (Gurr, 1970), (Runciman, 1966b). According to the theory of relative deprivation, people who feel satisfied with their current condition are less likely to seek social change. Thus, this theory proposes that social movements arise due to people’s perception of being mistreated.
Therefore, relative deprivation refers to the dissatisfaction a social group may feel when it compares what it obtains with what is obtained by similar groups, and concludes that it is not receiving what it deserves (Orum, 1974). According to this theory, movements are more likely to occur in contexts in which high development expectations have been generated, followed by economic contractions. This combination produces a phenomenon of unfulfilled expectations, or at least expectations that are fulfilled more slowly. The latter is of particular interest, given the economic contraction caused by the current global pandemic, which produces unfulfilled expectations in many countries that had optimistic pre-pandemic growth estimates.

Relative deprivation, as its name indicates, is a subjective measure that depends on how the social group is perceived in comparison to another similar group; in fact, it has been defined as a mental state that results from the discrepancy between the expectations of the people and the quality of life they obtain (Gurr, 1970). It must, then, be differentiated from the concept of absolute deprivation or poverty. For relative deprivation, comparison with a peer group is critical, while for poverty there are standard definitions (e.g., an income level of individuals and households or the Multidimensional Poverty Index of the United Nations Development Program). For example, a social group could obtain higher income, modifying their level of absolute deprivation; however, when compared to another group, they still perceive themselves as being at a disadvantage, and thus, their relative deprivation will not vary.

The recognition of the state of deprivation, called cognitive relative deprivation, can be the origin of feelings of frustration, disappointment, and anger, known as affective relative deprivation (Cook et al., 1977), (Dubé & Guimond, 1986), (Walker & Pettigrew, 1984). This affective deprivation can lead to actions that aim to reduce the unwanted feelings. When those actions seek to reduce self-deprivation, it will be defined as selfish relative deprivation, while if they aim to minimize group deprivation, it is defined as fraternal relative deprivation (Runciman, 1966b), (Martin & Murray, 1983).

The perception of deprivation refers to the resources that an individual receives. There could be a sentiment of injustice regarding social approval or cultural value. However, this research will concentrate on the perception of deprivation based on the resources people receive and, specifically, on what they receive from the state. Thus, the focus of attention will be on the perception of deprivation that arises from public investment strategies.

Given that the existing literature addresses relative deprivation from a qualitative or descriptive approach, a methodology is proposed in the following section to measure the relative deprivation quantitatively by expressing it in the form of a relative deprivation index (RDI), which is understood as an indicator of the potential for the satisfaction/discontent of citizens.

2.1 Measurement of the potential for satisfaction/dissatisfaction generated by current public investment

We noted that citizens who perceive themselves to be more satisfied with their current situation than others (or who perceive themselves as less deprived) are less likely to initiate or participate in social movements that could lead to violent riots. Then, it is important for any public administration to measure whether or not the citizens perceive that they are receiving what they deserve, to identify developing sources of discontent, and act accordingly.

Just as poverty or absolute deprivation is measured with multiple factors and indicators, we proposed to measure the relative deprivation of a social group i (RDIi) as indicated in (1):

$$ RDI_i = Q_i + E_i + N_i $$

where
\( Q_{ip} \): Total per capita public investment assigned and executed in social group \( i \) compared to the mean of its reference groups, adjusted by the weight social group \( i \) gives to the total amount transferred (2).

\[
Q_{ip} = P_q \cdot \left( \frac{Q_i - \mu_q}{\mu_q} \right)
\]  

(2)

\( E_{ip} \): Execution level of public investment per capita in social group \( i \) compared to the average of its reference groups, adjusted for the weight social group \( i \) gives to budget execution (3).

\[
E_{ip} = P_e \cdot \left( \frac{E_i - \mu_e}{\mu_e} \right)
\]  

(3)

\( N_{ip} \): Level of resources per capita executed in the priority areas of social group \( i \) compared with the average of its reference groups, adjusted for the weight social group \( i \) gives to execution in priority areas (4).

\[
N_{ip} = P_n \cdot \left( \frac{N_i - \mu_n}{\mu_n} \right)
\]  

(4)

where

\[
\mu_i = \frac{1}{N} \sum_{i=1}^{N} \xi_i, \ i = \{ q, e, n \}
\]  

(5)

\[
P_q + P_e + P_n = 1
\]  

(6)

2.2. Case study, part 1: Calculation of current satisfaction/dissatisfaction potential

After describing the proposed methodology for calculating the RDII, it will be applied to the seven communes of the Tarapacá Region, Chile, to evaluate the potential for current satisfaction/discontent.

The Tarapacá region is located in the extreme north of the country. It includes the communes of Iquique, Alto Hospicio, Huara, Pozo Almonte, Pica, Camiña, and Calchane, with 330,558 inhabitants in 42,225 km² (Biblioteca del Congreso Nacional, Región de Tarapacá, 2020).

Using the previous section's methodology, the RDII was calculated for each of the seven communes (i). The reference group of each commune comprised its neighboring communes.

Regarding the data source, the investment levels in the region and its communes were obtained from the database of the Public Program for Regional Investments (PROPIR, for its acronym in Spanish; SUBDERE, Subsecretaría de Desarrollo Regional y Administrativo, 2020), (Ley De Presupuestos del Sector Público año 2019, 2018). In each commune, the weight or importance assigned to the three factors (Qip, Eip, Nip) was determined from a survey of the corresponding population and civil society representatives. Through the same study, data were collected to define the factor Level of resources executed and invested in priority areas (Nip); that is, residents were consulted to determine the areas that they consider a priority. The survey profile is detailed below:

(a) Technique: A quantitative study based on cell phone interviews using computer-assisted telephone interview (CATI).

(b) Target Group: Men and women over 18 years of age, of all socioeconomic levels, residents in the seven communes of the Tarapacá region.

(c) Sample: Simple random sampling with an infinite population; the margin of error is 5% under the assumption of maximum variance and 95% confidence. The number of residents and representatives of civil society³ is listed in Table 1.
The data were population-weighted at the subject level by commune, sex, age, and socioeconomic status, to obtain a representative sample of the region.

Fieldwork: August 13–18, 2020.

The main objective of the survey was to determine the weight or importance that the inhabitants of each commune assign to the three factors (Qip, Eip, and Nip) of the RDI, and to define the three areas that neighbors consider to be priorities to determine which sectors will be taken into account for the calculation of the Nip factor.

After processing the 431 interviews carried out with the residents of the Tarapacá Region, both the weight of the factors and the areas considered priority were obtained (Tables 2, 3).

After applying the methodology described in Section 2 and considering the population survey results, the RDI was obtained for the seven communes of the Tarapacá Region. The results are detailed in Table 4.

The resulting RDI for the seven communes of the region in January–August 2020 (Table 4, Figure 3) indicates the potential for satisfaction/dissatisfaction in each of them. The lower the value, the lower the potential for satisfaction (or higher the discontent) and vice versa.

The factor of investment in the areas of greatest need (Nip) can drag the index up or down, while in other cases, it is compensated for by the action of the remaining factors (Qip, Eip). A local public
authority, such as the mayor, can consider the RDI and its factors to achieve the potential for more satisfaction/disscontent. Given that each commune has different values for different factors (Table 2) and priority areas (Table 3), the planning of the authority about which projects to execute, in which location, and when to carry them out is vital for the potential for satisfaction/dissatisfaction (Figures 4, 5, 6, 7, 8, 9, 10).

Consequently, each authority may seek to balance the execution of its portfolio of projects (emblematic, in areas of immediate need, in the medium or long-term, etc.) to maximize the potential satisfaction/dissatisfaction. The emphasis should be placed on the concept of potential,
because the RDI should not be interpreted as a direct and linear translation into satisfied or dissatisfied citizens. This will depend on the dynamics that are generated in the social system, which include variables such as preferences, culture, social pressure, and public investment strategies. How the RDI is translated into satisfied, indifferent, and dissatisfied citizens will be addressed in the following sections with the use of a cellular automaton (CA).

3. Model for translating the potential into satisfaction/dissatisfaction

Thus far, we have seen how social movements can emerge from the perception of deprivation. An index was proposed and calculated to measure the potential for satisfaction/dissatisfaction that such poverty can generate. It was also established that the RDI does not directly translate into more or less satisfied citizens as satisfaction depends on the interaction of multiple factors, such as social pressure, citizens’ political profile, public opinion, and the investment strategy of authority (with their own goals and interests). In this section, a model that integrates these concepts is proposed.
Public administration faces the challenge of comparing and evaluating available alternatives to solve social problems (Weimer & Vining, 2017). To meet this objective, multiple stakeholder interests must be considered, such as the vision of the local authority versus that of the central administration, the emblematic projects of the regional authorities, the influence on investment decisions of the electoral periods, the phenomenon of centralism, the influence of the media, and the priorities of civil society.

A social system in which authority and citizens interact does not behave in a deterministic way, so a causal formulation is not sufficient for its analysis; we must try to represent these relationships in a simplified way to better understand how the desired result could be reached (maximizing the level of satisfied citizens). These simplified representations are generally known as models.

Models help us understand phenomena and find cause-and-effect relationships, and they range from simple mental models to more advanced quantitative ones. However, as indicated above, the social system in which investment policies are implemented cannot be explained with purely quantitative models (there is no perfect information, people’s behavior is not always the same, etc.).

Classic statistical and data analysis procedures look for correlations that yield a unique result and, incidentally, ignore underlying causes. The methodology to be considered should allow authorities to carry out experiments and test their hypotheses, to find possible causal relationships that may not be obvious, and at the same time, be a tool for evaluating policies that deliver results close to the desired one.

Thus, simulation-based models seem adequate for evaluating public investment policies. These models capture complex relationships in systems, such as the financing of programs and the production rate (Forrester, 1969), and phenomena such as the segregation that occurs in the population from a small change in the preference for a race of the residents of a neighborhood (Schelling, 1978). Works such as that of Schelling (Schelling, 1978) demonstrate the importance of experimentation and the search for underlying and even anti-logical causes. Subsequently, with technological advances, computer-based simulations have made it possible to experiment with dynamics such as competition for resources, cultural transmission, urban planning, and the spread of pathogens (Epstein & Axtell, 1996).

As a type of simulation model, the CA provides a group of tools that meet the challenge of comparing and evaluating public investment policies. The CA allows the definition of cells with a behavior described by rules, which interact autonomously with their neighbors in a specific space.
called a grid. Furthermore, each cell, depending on the rules, can maintain or change its state (commonly two possible states: 1 and 0, on and off, etc.; Figure 11).

In formal terms, the model can be expressed as (7):

$$CA = (L, S, N, f)$$

(7)

donde

- CA: cellular automata.
- L: matrix with dimension d.
- S: the possible finite states of each cell.
- N: n possible neighbors.
- f: transition function, which defines a cell’s change from one state to another. (f: Sn → S).

In the next section, we will continue to examine the case of the Tarapacá region, this time comparing future investment alternatives, identifying the underlying dynamics, and evaluating which one delivers a higher level of satisfaction or dissatisfaction among citizens.

### 3.1. Case study, part 2: Translation of the satisfaction/discontent potential (RDI) into satisfied, indifferent, and dissatisfied citizens

This section involves applying a CA to evaluate how the satisfaction/dissatisfaction potential (RDI) translates into satisfied, indifferent, and dissatisfied citizens. The Tarapacá region’s capital, Iquique, was selected for this deeper analysis.

In general terms, the experiment considers agents (citizens) to be in an unsatisfied, indifferent, or satisfied state, under an interaction structure or rules, in a space or grid (the commune). The state of each agent can change after each iteration (period) depending on the rules.

To determine if an agent maintains or changes its state, the value of three factors is evaluated in each new period contrasted with the model’s rules. The elements evaluated in each iteration are...
(a) Current state of the cell: possible values of 1, 2, 3 (dissatisfied, indifferent, or satisfied).

(b) State of most neighbors of the cell: possible values of 1, 2, 3 (dissatisfied, indifferent, or satisfied).

(c) The expected RDI for the period or iteration, where:

- If the city’s RDI is in the upper third of the observations, it will take the value 3 (satisfied).
- If the city’s RDI is in the second third of the comments, it will take the value 2 (indifferent).
- If the city’s RDI is in the last third of the observations, it will take the value 1 (unsatisfied).

The rules will then define whether a cell (citizen) is in a satisfied, indifferent, or dissatisfied state depending on the combination of the three factors. Thus, for example, the 3: 1: 1 = 1 rule tells us that if a citizen is currently satisfied (3), with mostly dissatisfied neighbors (1) and in a city with an RDI in the lower third (1), then that agent/neighbor will convert to or remain in the dissatisfied state (1).

Note that the group of rules that models the cells’ behavior makes it possible to reflect the profile of the commune and its citizens. For example, with a polarized public opinion, only a single (or no) rule can be defined that leads from satisfied to dissatisfied and vice versa (in the current case, two rules are defined in each case: 1: 3: 2 = 3, 1: 3: 3 = 3 and 3: 1: 1 = 1, 3: 2: 1 = 1).

In addition, the RDI depends directly on the public investment strategy to define different systems and evaluate the number of satisfied, indifferent, and dissatisfied citizens they produce and in how much time (periods).

In total, three strategies were tested to determine which one generates the highest level of satisfaction in the shortest time. Each approach distributed the same RDI levels differently to reflect that it was simulating the same budget, which can be managed differently over time.

The input parameters in the system were defined as follows:

(a) Grid size: 50 × 50 (2500 cells).
Table 4. RDI per commune, January-August 2020

|       | Jan   | Feb   | Mar   | Apr   | May   | Jun   | Jul   | Aug   |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Qip   | 0.370 | −0.414| −0.715| −0.750| −0.741| −0.709| −0.717| −0.717|
| Eip   | 2.463 | 0.893 | 0.225 | 0.071 | 0.093 | 0.203 | 0.181 | 0.180 |
| Nip   | −0.778| −0.826| −0.953| −0.967| −0.962| −0.932| −0.937| −0.937|
| RDI   | 0.316 | −0.269| −0.576| −0.634| −0.624| −0.570| −0.580| −0.581|
| HUAR  | Jan   | Feb   | Mar   | Apr   | May   | Jun   | Jul   | Aug   |
|       | 0.239 | 0.765 | 1.001 | 0.735 | 0.802 | 0.774 | 0.837 | 0.846 |
| Eip   | −0.451| 0.002 | 0.508 | 0.303 | 0.337 | 0.288 | 0.344 | 0.351 |
| Nip   | −1.000| −1.000| 0.393 | 0.099 | −0.227| 0.015 | −0.062| −0.056|
| RDI   | −0.646| −0.430| 0.521 | 0.258 | 0.100 | 0.213 | 0.197 | 0.204 |
| COLC  | Jan   | Feb   | Mar   | Apr   | May   | Jun   | Jul   | Aug   |
|       | 0.239 | 0.765 | 1.001 | 0.735 | 0.802 | 0.774 | 0.837 | 0.846 |
| Eip   | −0.347| −0.181| 0.387 | 0.487 | 0.564 | 0.517 | 0.582 | 0.579 |
| Nip   | −0.750| −0.598| −0.097| −0.035| 0.003 | −0.048| 0.000 | −0.001|
| RDI   | −0.646| −0.430| 0.521 | 0.258 | 0.100 | 0.213 | 0.197 | 0.204 |
| AHOS  | Jan   | Feb   | Mar   | Apr   | May   | Jun   | Jul   | Aug   |
|       | −0.549| −0.757| −0.846| −0.726| −0.689| −0.677| −0.684| −0.685|
| Eip   | −0.186| −0.439| −0.528| −0.163| −0.061| −0.045| −0.059| −0.060|
| Nip   | −1.000| −0.981| −0.742| 0.235 | 0.254 | 0.166 | 0.090 | 0.089 |
| RDI   | −0.684| −0.782| −0.693| −0.032| 0.015 | −0.026| −0.073| −0.074|
| PICA  | Jan   | Feb   | Mar   | Apr   | May   | Jun   | Jul   | Aug   |
|       | −0.198| −0.629| −0.568| −0.486| −0.520| −0.487| −0.501| −0.502|
| Eip   | −0.726| −0.838| −0.750| −0.703| −0.726| −0.713| −0.720| −0.720|
| Nip   | 3.258 | 1.034 | −0.532| −0.737| −0.760| −0.727| −0.750| −0.750|
| RDI   | 1.529 | 0.214 | −0.598| −0.680| −0.706| −0.678| −0.695| −0.695|
| PALM  | Jan   | Feb   | Mar   | Apr   | May   | Jun   | Jul   | Aug   |
|       | 0.157 | 0.837 | −0.190| −0.300| −0.341| −0.327| −0.341| −0.343|
| Eip   | 0.120 | 1.275 | 0.332 | 0.147 | 0.066 | 0.066 | 0.051 | 0.049 |
| Nip   | 1.520 | 0.714 | −0.590| −0.663| −0.599| −0.589| −0.623| −0.623|
| RDI   | 0.980 | 0.879 | −0.295| −0.403| −0.390| −0.382| −0.409| −0.410|
| CAMI  | Jan   | Feb   | Mar   | Apr   | May   | Jun   | Jul   | Aug   |
|       | 0.327 | 0.380 | 0.931 | 1.039 | 0.926 | 0.909 | 0.825 | 0.821 |
| Eip   | −0.470| −0.294| 0.311 | 0.380 | 0.288 | 0.249 | 0.203 | 0.201 |
| Nip   | −1.000| 0.981 | 1.668 | 1.237 | 0.639 | 0.587 | 0.455 | 0.454 |
| RDI   | −0.602| 0.455 | 1.093 | 0.918 | 0.570 | 0.528 | 0.433 | 0.431 |

(b) Number of iterations (periods): 10. A level of public investment called a strategy is defined in each.

(c) Each iteration represents a semester to reflect that the budget is executed in the first one. In the second semester, adjustments are made according to the progress status.

(d) The borders are assumed to have a fixed value equal to the one obtained in the initial iteration (fixed value boundaries).
(e) The initial state by type (iteration 0 or seed) is 1 = 1000, 2 = 500, and 3 = 1000 for the 2500 cells of the grid.

(f) Three strategies were evaluated (Table 5):

- E1: Bell-shaped strategy.
- E2: Start high, ends low strategy.
Figure 12. PPACEL: user interface.

Table 5. Strategies tested

| Strategy           | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|--------------------|---|---|---|---|---|---|---|---|---|----|
| Bell-shaped        | 1 | 1 | 1 | 2 | 3 | 3 | 2 | 1 | 1 | 1  |
| Start high, ends low | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1  |
| Start low, ends high | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 3  |

- E3: Start low, ends high strategy.

(g) The rules that define the interaction of cells are indicated in Table 6.

3.2. Results and PPACEL System

A software was developed to implement the above model. The results obtained are presented in Table 7, whereas Figure 12 shows the online system's output. The results for the evaluated strategies can be accessed as follows:
Figure 13. PPACEL: cells status evolution.

Table 6. Set of rules

| Rules          | Type 1 | Type 2 | Type 3 |
|----------------|--------|--------|--------|
| 1: 1: 1 = 1    | 2: 1: 1 = 1 | 3: 1: 1 = 1 |
| 1: 2: 1 = 1    | 2: 2: 1 = 1 | 3: 2: 1 = 1 |
| 1: 3: 1 = 1    | 2: 3: 1 = 1 | 3: 3: 1 = 2 |
| 1: 1: 2 = 1    | 2: 1: 2 = 2 | 3: 1: 2 = 2 |
| 1: 1: 3 = 2    | 2: 1: 3 = 2 | 3: 1: 3 = 2 |
| 1: 2: 2 = 2    | 2: 2: 2 = 2 | 3: 2: 2 = 3 |
| 1: 2: 3 = 2    | 2: 2: 3 = 3 | 3: 2: 3 = 3 |
| 1: 3: 2 = 3    | 2: 3: 2 = 3 | 3: 3: 2 = 3 |
| 1: 3: 3 = 3    | 2: 3: 3 = 3 | 3: 3: 3 = 3 |

- E1: Bell-shaped strategy. [http://www.ppacel.com/e1/](http://www.ppacel.com/e1/)
- E2: Start high, ends low strategy. [http://www.ppacel.com/e2/](http://www.ppacel.com/e2/)
• E3: Start low, ends high strategy. http://www.ppacel.com/e3/

The application of CA aims to address three goals: (1) determine what would happen to the levels of satisfaction, indifference, and dissatisfaction in the future if one or another investment strategy is implemented; (2) evaluate the dynamics that are generated by one or another alternative; and (3) develop a user interface that allows the evaluation of new strategies and display of their results.

|  | s0 | s1 | s2 | s3 | s4 | s5 | s6 | s7 | s8 | s9 | s10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| E1 sat | 998 | 878 | 881 | 883 | 254 | 104 | 88 | 87 | 84 | 86 | 88 |
| E1 ind | 501 | 1283 | 1458 | 1509 | 2138 | 238 | 50 | 39 | 1625 | 2143 | 2273 |
| E1 dis | 1001 | 139 | 128 | 99 | 90 | 89 | 89 | 89 | 89 | 89 | 89 |
| E2 sat | 1001 | 414 | 128 | 99 | 90 | 89 | 89 | 89 | 89 | 89 | 89 |
| E2 ind | 500 | 212 | 48 | 57 | 41 | 1638 | 2128 | 2268 | 2314 | 2324 | 2328 |
| E2 dis | 999 | 1874 | 2324 | 2344 | 2369 | 773 | 283 | 143 | 97 | 87 | 83 |
| E3 sat | 999 | 828 | 828 | 828 | 828 | 828 | 828 | 214 | 100 | 71 | 68 |
| E3 ind | 501 | 1334 | 1509 | 1568 | 1584 | 1592 | 1594 | 2208 | 2322 | 286 | 70 |
| E3 dis | 1000 | 338 | 163 | 104 | 88 | 80 | 78 | 78 | 78 | 2143 | 2362 |
(a) As indicated, the main objective is to know the total number of satisfied, indifferent, and dissatisfied cells (citizens) that each investment strategy delivers (reflected in the expected RDI) and in how much time (periods). The latter is important because during the periods of implementation of investment strategies, the election periods should ideally coincide with higher satisfaction levels. The results (Table 7) are provided in terms of the aggregate total of cells in the satisfied (sat), indifferent (ind), and dissatisfied (dis) states that are generated by each strategy and each period.

Thus, in period 10, the best choice is strategy 2 because it delivers more satisfaction and less dissatisfaction. Should this strategy be selected? The answer depends on external factors; for example, in those 10 semesters, there could be an election in period 4, and in that case, the best option would be strategy 3.

(b) The second objective is to identify the underlying dynamics in the model:

- In analyzing the results, it was observed that, as expected, the number of satisfied cells increases with a more effective strategy and decreases otherwise, in both cases with a transition through the indifferent or intermediate state. However, the reaction time to increase was different from that of a reduction. For example:
  
  * An upward strategy (Table 7, Strategy 3, iteration 6) takes effect after 3 periods; that is, the increase in satisfied cells is not generated automatically.

  * A downward strategy (Table 7, Strategy 1, iteration 6) translates into more dissatisfaction only if there is an abrupt transition (a strategy equal to 2 as a transition). However, it only translates into indifferent if the transition takes longer (Table 7, Strategy 2, iteration 2).

- Thus, public investment can be evaluated in terms of relative deprivation by measuring:

  * If a neighbor finds that more or fewer resources are invested locally than in another locality.

  * The capacity of the authority to execute the projects.

  * The direct relationship between what is needed and what is invested (these factors are directly related to the authority’s decision of how much and where to invest).

- However, it is possible to emphasize that the effect on satisfaction is not automatic and has a lagged effect, which also depends on the duration of the transition (both cases are observed in the illustrative case study). The latter is especially important when considering variables such as election periods and time in public office.

(c) The third objective is to design an interface that allows the local authority to enter the data into the model, modify it, and evaluate the results. The user interface currently allows the following:

- Evaluation of strategies and display of results aggregated by period (Figure 12).

- Display of the evolution of cells (agents) according to their status on the map of the commune (Figure 13).

- Comparison of the strategies (Figure 14).
4. Conclusions

The types of social movements and their evolution were analyzed, identifying the theory of relative deprivation as the cause of the gestation of these movements. In some cases, these movements can be the sources of social conflict.

The RDI was proposed to measure the potential for satisfaction/dissatisfaction in a geographic area quantitatively. Then, the use of a CA was proposed to evaluate how the potential for satisfaction/dissatisfaction (RDI) is translated into satisfied, indifferent, and dissatisfied citizens. In the CA, the RDI was used to measure the potential for satisfaction/dissatisfaction. In this way, the CA could reveal what would happen if the investment plans were modified and the reason for the effects (underlying dynamics).

The proposed methodologies focus solely on how public investment influences the levels of satisfaction/dissatisfaction, understanding that the greater or lesser level of perceived resources may influence but not necessarily fully explain the birth of a social movement. The model based on the RDI and CA approach may be used in other contexts in which satisfaction/dissatisfaction and public investment are evaluated. In the RDI, the result obtained depends on how the weight that the population gives to each factor and the investment areas that they consider priority are calculated. In the application of the CA, the result is linked to the researcher's ability to reflect the characteristics of the population in the model's rules and input variables.

In particular, the RDI is useful to evaluate which areas of investment are responsible for an increase in the potential for satisfaction/dissatisfaction. This is important because the Chilean public and state budgets consider multiple areas of investment. However, the RDI should not be interpreted as a direct and linear conversion into satisfied or dissatisfied citizens; this trend will depend on the dynamics that are generated in the social system, which include variables such as preferences, culture, social pressure, and strategies of public investment.

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Endnotes
1. The commune is the smallest Chilean territorial division for administrative purposes. In total, there are 346 grouped in 16 regions.
2. From now on the equivalent names will be used: Iquique (Iquique), Ahos (Alto Hospicio), Huar (Huara), Palm (Pazo Almante), Pica (Pica), Cami (Camiña) and Colc (Colchane).
3. For the survey, civil society representatives were understood as neighborhood councils, groups of older adults, sports clubs, etc.
4. Areas consulted: Health, Housing, Transport and Roads, Work, Crime, Education, and Culture.

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