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Influence of internal values and social networks for achieving sustainable organizations

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Abstract. The LOw Carbon At Work (LOCAW) project has studied the everyday behavior of employees in six organizations in order to achieve a more sustainable Europe. Of these six, four organizations were involved in backcasting workshops to obtain future scenarios aimed at significantly improving engagement with pro-environmental behaviors by 2050. From these scenarios policies were extracted from the workshop participants that achieve this aim in their organization. Agent Based Models (ABM) were designed to model the organizations using actual information from the organization; the design also placed special emphasis on the representation of the social network. ABMs were then used to simulate the effects of the different policies derived from the backcasting scenarios. In this paper, the results for two organizations, UDC and Aquatim, are shown. These experimental results demonstrate the influence of different social networks and internal motivations of employees to determine the effectiveness of a given policy.

1 Introduction

European Union leaders have endorsed the objective of reducing Europe's greenhouse gas (GHG) emissions by 80-95% compared to 1990 levels as part of efforts by a number of developed countries to make similar reductions in their emissions by 2050 [1]. The emissions generated by large organizations result from their production processes and the pressures under which they function within our economic system. Following the new EU regulations, national governments have also passed laws concerning emissions and have created policy instruments designed to reduce or compensate the level of emissions of specific organizations in order to reach national and European goals. As a result of these new regulations, organizations have also started to implement mechanisms to reduce their GHG emissions. However, these strategies have not been sufficient to ensure significant reduction rates. To better articulate efforts undertaken by relevant actors towards sustainability, the LOCAW project (*www.locaw-fp7.com*) set out to identify the barriers to, and drivers of, low-carbon transitions in workplaces across Europe, by systematically analysing everyday practices at work and home. This project investigated six large-scale organizations, operating under different national and international contexts. The six case studies fall into three types: two public organizations (one university and one municipality), two utility companies (water and energy), and two transnational heavy industry companies (truck manufacturing and oil and gas extraction).

In four of these cases (public organizations and utility companies), the focus has been on the everyday practices of the workers in the organization itself and the interactions between structural/organizational conditions and individual factors in generating barriers to and drivers for a transition to a low carbon Europe. For each organization, desired future states (at 2050) of aspects of the organization related to energy use, waste, and work-related mobility have been constructed through backcasting workshops. Backcasting is a method in which desired future goals are envisioned by workshop participants, who then identify the steps that need to be taken to achieve those goals [6]. To test the plausibility of these future states under a range of assumptions, ABMs have been used. ABMs are computational simulations of the actions and interactions of heterogeneous autonomous agents with a view to assessing their combined effects on the system as a whole. In social sciences, ABM has become increasingly popular: compared with more traditional tools in social sciences, including variable-based modeling approaches or other techniques based on differential equations or modeling equilibria, agent-based models offer the possibility of modeling individual heterogeneity, representing explicitly the decision rules for the agents, and locating them on a geography or other kind of space. It also allows the modelers to represent in a natural way multiple analytical scales, the emergence of structures at the macro or social level arising from individual action, interaction and adaptation and learning, which are analytically intractable or inelegant or impossible to express in transparent way with traditional modeling approaches. Although different organizations have been modeled, they all share a similar core based on a common ontology [10]. Agents, i.e. the employees of the organizations, follow a decision-making process based on actual data acquired by quantitative and qualitative tools [11]. Based on these previous works, this paper presents:

- The design of the social network that allows interaction among agents. This network is based on the information of the internal structure derived from the organization itself, so two networks - hierarchical and acquaintance - working in parallel are used. Both subnetworks were tailored for each organization.
- The modification in agent behavior due to the influence of these networks.
- Once the models are designed, several simulations have been run to test the feasibility of the proposals made by selected members of the organizations in the backcasting workshops. Some results for two of these organizations are presented in this paper, specifically, the University of A Coruña (UDC), a public university in

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Spain, and Aquatim, a company providing water and sanitation in the Timiş region of Romania (principal city Timişoara). These experimental results were theoretically analyzed by psychologists and sociologists in the LOCAW project.

Although the idea is to achieve a similar future scenario - a company that can reduce carbon emissions associated with the everyday behaviors of its personnel -, the experimental results are clearly different, showing that the success or failure of a given policy is influenced by the organization's social network and the internal motivations of their workers.

2 The designed ABM model

The LOCAW project uses ABM as a synthesis tool for representing everyday practices in the workplace pertaining to the three areas of interest for this project: the use of energy and materials, management and generation of waste, and mobility. The purpose of the ABM is to explore the impact of various measures and integrative themes (proposed in backcasting workshops and by the LOCAW consortium) on everyday pro-environmental behavior in the different case studies, of which this paper focuses on two: UDC, Spain and Aquatim, Romania. The model was implemented using Repast Simphony 2.1 (`http://repast.sourceforge.net/repast_simphony.php`) and the ODD protocol [3] has been used to describe the agent-based model, however space limitations do not allow its inclusion here.

Different quantitative and qualitative tools were used in LOCAW project to analyze the different organizations, including focus groups, interviews, and questionnaire surveys. The model aims to be evidence based, drawing on those data supplied by field researchers and other supplementary information. Among the different quantitative tools for data acquisition, a questionnaire was designed to obtain actual data from the workers that affect their decision to adopt pro-environmental behaviors. The questionnaire is based in the value-belief-model (VBM) proposed in the Workpackage 4 of the LOCAW project (see `http://www.locaw-fp7.com/userfiles/Deliverables/WP4_Deliverable_D4.3.pdf`). This questionnaire consists of four blocks of questions covering: (a) personal data, (b) values, (c) motivations, and (d) behaviors, as illustrated in the center of figure 1.

The model features persons (agents) who work for the organization following a daily routine that consists of several steps implemented by different methods (for example, `commute()`, `work()`, `eat()`). Each one of these methods will use at least one *Behavior*: a situation in which agents find themselves and they need to make a decision. The agent decides the behavior to exhibit based on its individual personal data, values and motivations (input data in figure 1). Decision trees were used to represent this decision-making process. The reason for using decision trees was that automatic decision tree learning algorithms could be deployed to create statistically-derived mechanisms to represent decisions of agents in each case study for each everyday behavior. This offered an empirical basis for representing decision-making. At the same time (and in contrast with other learning algorithms, such as neural networks), the results can be easily explained. In block (d) of the questionnaire, there were 74 questions covering the use of energy and materials, the treatment of waste and the use of transport both at work and in the home. Allowing for questions related to the same behavior, the questionnaire covered 60 different behaviors. The model also records the consequences of the decision made for a given behavior, so there are options preferred from a pro-environmental perspective because their impact (in greenhouse gas emissions) is lower; e.g. cycling to work would be preferred to going by car.

Besides individual behaviors, the organization is structured in different areas where agents interact with each other. The variable "maxRelations", obtained from the questionnaire, indicates the maximum number of agents a given respondent is able to see or interact with. To reflect these interactions in the current situation of the organizations, it was decided to model two social networks operating simultaneously: hierarchical relationships, or the vertical network that tries to reflect the management structure of UDC and Aquatim; and the relations of friendship and companionship, or horizontal network. Finally, according to backcasting workshops, different policies were obtained. These policies try to promote or even to obligate more pro-environmental behavior at work by using, for example, information campaigns (e.g. promoting using the bicycle instead of the car). Such policies affect the internal values of the agents, so that the decision derived for the corresponding behavior may change to select the more pro-environmental option.

Subsequent subsections present the decision-making process, both social networks for UDC and Aquatim, and explain how interactions among agents modify their motivations, changing their behavior.

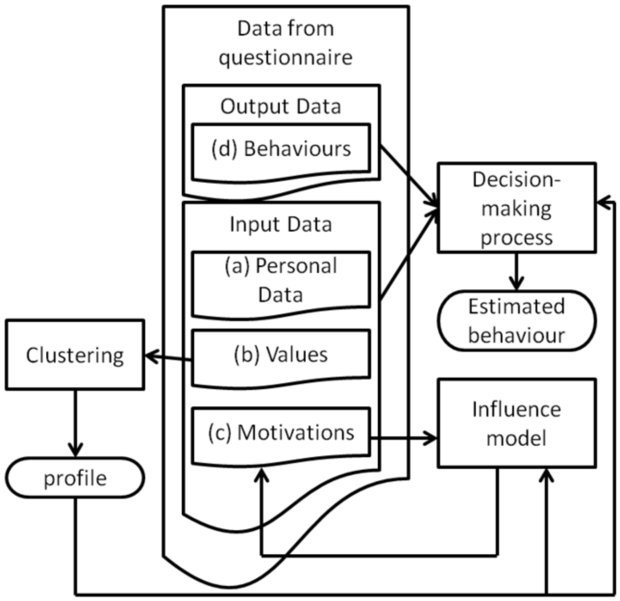


Figure 1: General schema to reflect data used for each model: decision-making and influence.

2.1 The decision making process

The information and data collected by researchers in the LOCAW project have been used to automatically obtain classification trees that model the agents' pro-environmental decisions for everyday behaviors. However, before using decision-trees to determine the option elected for a given behavior of the agents, some techniques have been applied to obtain a representative set of data that maximizes the generalization capability of the resulting decision trees. Specifically, clustering, feature selection and proportional k-interval discretization [13] were applied; all these methods are available in the Weka tool [5]. This section briefly explains the aim of these techniques. Further details can be found in [11].

Answers in the questionnaire related to values (block (b)) were used to identify four different profiles (biospheric, altruistic, egoistic and hedonic) with the expectation that respondents with different profiles would behave in different ways. Clustering techniques were applied to identify those profiles from the questionnaire responses, however none of the partitions obtained for UDC and Aquatim allowed for clearly distinguishing the profiles as indicated by the experts working in the project. Finally, in discussion with the experts, six and four clusters were identified for UDC and Aquatim, respectively, which enable adequate separation of the available responses and contain hybrid groups. Specifically, for the UDC case study, four profiles matching the theoretical ones: egoistic, altruistic, biospheric and hedonic, and two more hybrid groups that mixed similar profiles (biospheric-altruist and egoistic-hedonic) were obtained. However, only five profiles were considered for inclusion in the model because the Egoistic profile had only two respondents, and these two egoistic persons were added to the hybrid profile (hedonic-egoistic). On the other hand, three of the four clusters of Aquatim are hybrid and the remaining one is the egoistic profile. After that, a decision tree is going to be constructed for each behavior and each profile.

The number of responses for the questionnaire was not very high (around 200 and 100 for UDC and Aquatim, respectively) and the questionnaire is composed of 64 questions in blocks (a), (b) and (c), so the ratio of samples to features is low. Hence, feature selection methods were applied to determine the relevant features while eliminating the irrelevant or redundant ones [4] with the aim of increasing the generalization capability of the decision trees. Furthermore, a discretization step was included because the number of possible responses to most of the questions is a Likert-scale (possible answers in the range 1-7), however many responses were clearly skewed, so different intervals were generated for each response in order to obtain more balanced distributions.

Finally, once the data are pre-processed by the techniques described above, the C4.5 algorithm [8] was used to derive a decision tree for each behavior for each profile. Bearing in mind that there are around 60 behaviors and 5 and 4 profiles for UDC and Aquatim, respectively, the number of decision trees is extremely large. However, all the decision trees derived from both organizations were consistently checked in both directions, from the point of view of data (i.e., good balance between training and testing data in C4.5 algorithm) and from the viewpoint of experts. That means that all the trees were reviewed in detail by experts and they are in accordance with the theoretical studies in the field.

2.2 Social networks

There are currently four basic types of models of networks: regular lattice, small- world, scale-free and random [12]. However, while these models accurately reflect some real networks, they do not seem to be very good models of social networks. For that reason, as stated previously, to model UDC and Aquatim organizations, it was decided to model two networks based on actual data of the organizations: the vertical network that represents the managerial relationships and the horizontal network that includes relations of friendship and companionship. Before explaining the social networks, it is important to say that there exist two main collectives in the UDC: academic personnel and administrative personnel, called PDI and PAS, respectively, by their acronyms in spanish and those collectives have different social networks. However, there are no collectives in Aquatim. The designed networks are:

- The vertical network. The hierarchical network tries to reflect the management structure of the organization. Therefore, we have used a directed graph with the relation *is-managed-by* (inverse *manager-of*), so that each agent points to other agents (usually only one) who are somehow responsible for it. The hierarchical structure depends on the position of the agent in each organization. Thus, using the vertical network, we can provide a transmission of rules and policies that are implemented in a hierarchical manner through the governing bodies of the organization, in the case of the university: presidency of the university, deanship, etc.
  For UDC, on the one hand the PAS (administrative personnel) are managed by the head of service, and each of them in turn is managed by a single general manager who in turn is managed by the President. On the other hand, PDI personnel are managed by the head of the research group, the director of the department to which they belong, and the dean of the faculty where they work. Each PDI agent belonging to each of these three upper levels is managed, in turn, by the President of UDC.
  The Aquatim hierarchical network reflects the actual organization chart which is similar to the PAS network for UDC. In that way, Aquatim top managers occupy the top positions of the hierarchy (formed by six persons: the general director and five directors of departments), followed by managers, then supervisors and finally, the different operators. However, there are some operators that may be managed by managers, or even top managers, without any supervisor between them.
  Regarding the evolution of these networks, the topology remains static, although some agents vary over time to represent the adhesion of new agents (hiring / new position) for different services, groups, departments, and the removal of old agents (retirement / change destination).
- The horizontal network. There is a transmission of norms through social relations beyond the hierarchical structure of the organization. These are given by the personal interaction that the actors have with each other in their daily lives. This other reality is represented by the horizontal network. The horizontal network is built from the hierarchical network using knowledge acquired from both organizations, UDC and Aquatim.
  The set of relations of friendship and companionship will also be represented by a graph, with undirected edges, since these relationships are assumed to be reciprocal. This network is much more dynamic, and agents can change those they relate to dynamically, creating and removing links on a regular basis. The proposed model for the evolution of these networks is based on studies in [7]. The principle of the model is that two unlinked agents are more likely to find and to create a relationship when they have more relationships in common. Although new links may appear every day in any organization, to save computational resources, time periods in which the network evolved in the model were established based on knowledge of the organizations. Thus, in the case of the university, the changes are carried out on a semester basis, while in Aquatim the changes are done annually.

2.3 Influence model

The agents' decision-making process is determined by two factors: first, by the decision tree derived for that agent using the data acquired from the questionnaire and second, by the influence exerted by agents that are linked to a given agent using both networks (horizontal and vertical). Since the behavior of the agents should vary over time, as in the real world, the decision trees, the social network, or both, must change to modify agent behavior. As there are no future data, decision trees remain static. Hence, in order to change the behavior of an agent with respect to a decision tree, a mechanism to modify its internal parameters is needed so that the output of the decision tree for that specific agent might vary. Some internal values of the agent (those in block (a) of the questionnaire) are not influenced by social pressure (sex, education level, etc.), however there are some parameters that are notably affected by the relationships of the agent: motivations. The idea is based on the fact that agents tend to assimilate the behavior of others after observing them, to a degree that is related to (i) the ability to perceive norms, (ii) the ability to broadcast norms to other agents within its social network, and (iii) the affinity that it has with them; agents having greater affinity with those agents that have values similar to theirs (as measured by the values profile to which they belong). Configurations for perceiving and transmitting norms ((i) and (ii)) were derived from the questionnaire. If an agent has high perception of norms, it will change its motivations very often, although slightly. Similarly, if an agent exerts high influence over others, it will affect others so that they modify their decisions.

It is worth mentioning that the model can vary both the influence of the hierarchical social network (in both directions, from supervisors to subordinates and vice versa), and the influence of horizontal social network. In UDC case study, the horizontal social network performs all the influence, while the vertical network has no influence, i.e., agents in the horizontal network affect an agent decision, but supervisors and subordinates do not. This was done to reflect the high degree of autonomy that the workers in UDC have, where there is little personal contact with supervisors (department head, dean, president). By contrast, the hierarchical network has more influence in Aquatim than horizontal network. Specifically, the influence of supervisors, co-workers and subordinates account for 50%, 35% and 15%, respectively. This means that the vertical network has more influence than the horizontal one (65% vs. 35%) and, in the vertical network supervisors have more influence over subordinates than vice versa.

3 Designing policies

In LOCAW after obtaining a complex picture of the barriers to and drivers of sustainable practices at the present time through the different studies of the workpackages, the backcasting workshops allowed the development of a set of dynamic and normative perspectives on the future of each organization in 2050. Backcasting is central for a strategic approach to planning for sustainable development. This methodology works by defining a desirable future and then works backwards to the present time in order to identify policies and programs that will connect the future to the present, assessing its feasibility. Backcasting is usually a long-term exercise, in terms of business planning, and is increasingly used in urban planning and resource management of water and energy. It has gradually become more popular and more widely applied over the last decade [6, 2, 9].

In LOCAW project, backcasting was done following a participatory and inclusive approach. In each organization an informal meeting was arranged with members of staff covering different levels in the organization and involving, as far as possible, members of the environmental management team. For example, the UDC meeting included members of the environmental office (OMA), as well as researchers for different fields such as civil engineers, biologists and so on. From these meetings, three future scenarios were envisioned. The first scenario is the most conservative, with changes caused mostly by the evolution of technology without significant changes in the structure of the organization. At the opposite extreme, the third scenario has a more divergent view, with great technological advances and organizational changes (in the case of UDC, the university disappears in favor of a single European university). The second scenario is halfway between these two scenarios. From those scenarios, different possible policies to implement in the ABM were proposed, covering the three topics (mobility, energy and waste) of the LOCAW project. Furthermore, psychologists working in the project were interested in other means of bringing about change, for example, to check the influence of different motivations. Several policies were tested so as to check their effectiveness and next section presents some of the results achieved.

4 Experimental results

From the three scenarios derived from the backcasting sessions, many different ideas were obtained to achieve more sustainable organizations. Some of them were introduced in the model by means of parameter changes, for example, one scenario included reduced CO_2 emissions from transport due to technological advances, and the model simply adjusted relevant parameters to reflect this decrease in emissions at the appropriate time. The model can simulate mixtures of policies. In this case the configuration is more complex, as it involves several parameters and is made via a configuration file. From the several simulations carried out, this paper shows an example for each of the three areas of pro-environmental behavior covered by the LOCAW project:

- Mobility: restricting the use of the car.
- Energy and materials consumption: promoting use of recycled paper.
- Waste generation: paper recycling.

In addition, following suggestions made by the team of psychologists, simulations showing the influence of different motivations for both organizations were conducted.

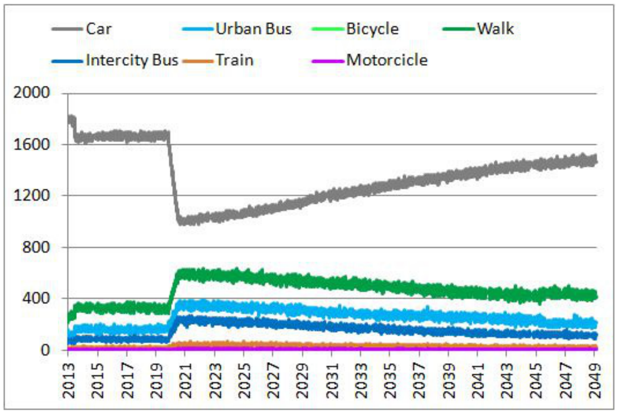
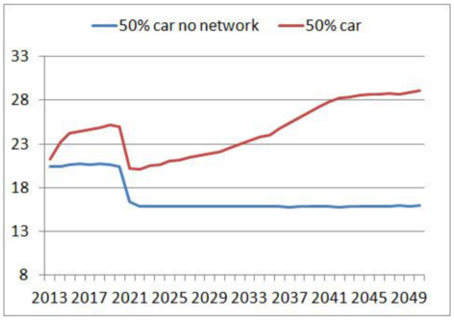


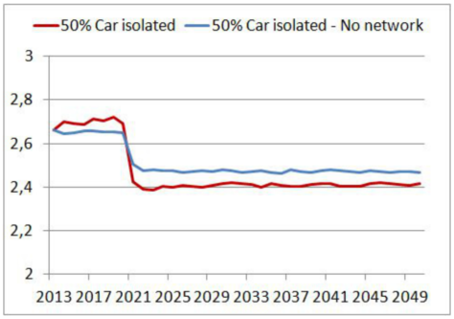
Figure 2: UDC. Evolution of means of transport when applying a policy for reducing car use in year 2020 (number of agents using the mode of transport vs date).

4.1 Mobility: reduce car use

Most CO_2 emissions of UDC are due to mobility (around 80%) and, as it can be seen at year 2013 in Figure 2, most workers go to work by car, so emissions could be significantly reduced if this behavior is modified by employing other means of transportation. For that reason, one of the experiments simulates the effects of applying a policy restricting the use of the car, at a single point in time (reducing the use of car at 2020). Figure 2 illustrates the effect of this policy: the agents react by using other means of transportation, but car use gradually recovers and eventually exceeds its original level due to the influence of the social network of the agents, as it can be seen in the figure 3a. These results demonstrate that social networks can be highly influential on the results obtained. Unlike UDC, most Aquatim employees go to work using public transport in 2013 as shown in figure 4. The results obtained after applying the same policy of reducing car use in Aquatim are markedly different from those of the UDC, as the reduction achieved following implementation of the policy is stable over time. This stability may be due to the strong hierarchical nature of this organization, with the consequence that the impact of the horizontal network is smaller (see figure 3b).



(a) UDC



(b) Aquatim

Figure 3: Influence of social network when applying a policy of car reduction (CO_2 tons vs date).

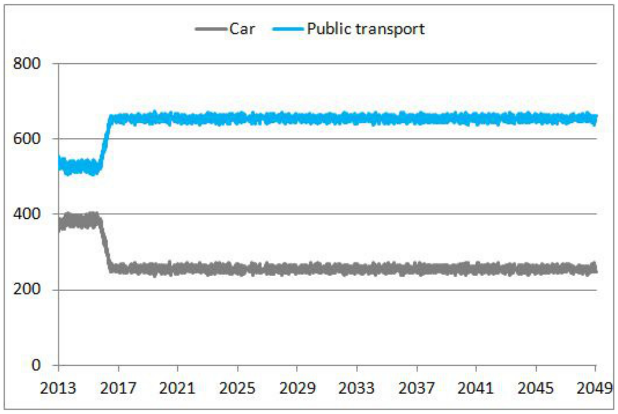


Figure 4: Aquatim. Evolution of means of transport when applying a policy for reducing car use (agents vs date).

4.2 Materials consumption and treatment of waste: increase recycling

The model includes a policy of promoting the use of recycled paper, thereby covering another aspect of the LOCAW project: materials consumption. The waste domain of everyday practice researched by LOCAW is explored in the model by testing a policy that promotes recycling paper.

Figure 5 shows in green the number of agents that recycle paper, the discontinuous line corresponds to a situation without campaigns, while the continuous one corresponds to a campaign trying to raise awareness about recycling for UDC, run in year 2026. The situation reflects that the campaign is very effective, and that the agents incorporate the behavior that, in contrast to the previous case of car reduction, does not decrease, but remains stable. Users of recycled paper is depicted in blue colour, the campaign (run in year 2016) is also effective, although here apparently the social network affects the behavior and the number of users slightly diminishes achieving some stability in the long term.

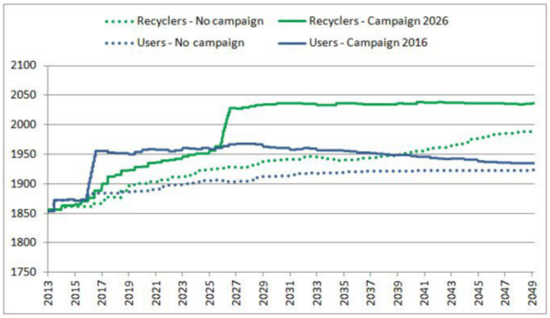


Figure 5: UDC. Comparative study on recycling (agents vs date).

Similarly, figure 6 shows the results for Aquatim when a recycling paper scenario is simulated, also considering both campaigns: use of recycled paper and paper recycling, using the same years as UDC. As it can be seen, the number of agents increases with the campaign and then diminishes progressively, in a more or less similar way to what happened in UDC with the car reduction scenario (see figure 3a). Here the behavior is not sufficiently emphasized by the organization to prevent the horizontal social network, although weaker than the hierarchical one, from acting such that the agents can react against the norm from management to recycle and use recycled paper. That said, the number of agents incorporating the behavior slightly is higher after the campaign than in the present situation. In the UDC case study, we found that the results on one campaign influenced the adoption of the other. In particular, the increase in the number of users of recycled paper provoked an increase in the number of recyclers. The inverse situation did not occur, that is, an increase in the number of recyclers

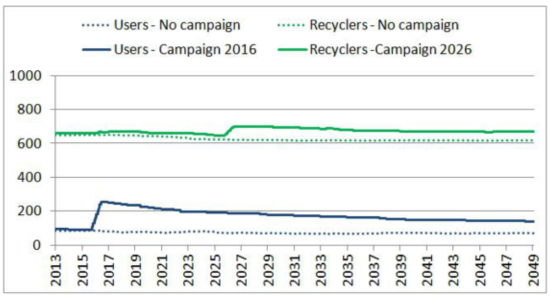


Figure 6: Aquatim. Comparative study on recycling (agents vs date).

did not imply an increase in the number of users of recycled paper. However, in Aquatim, there appears to be no relation between both campaigns.

4.3 Promoting higher motivations

As we have commented in section 2.1, the values and motivations -i.e., efficacy, identity and norms- of an agent affect its behavior. Therefore, higher values of efficacy, identity and norms were imposed for all agents to test possible changes in behavior when a car reduction policy is applied. The following simulations were done:

1. Apply car reduction policy (50% of reduction, isolated in a point in time).
2. Apply car reduction policy with higher values of : a) efficacy; b) identity; c) norms.
3. Apply car reduction policy with higher values of efficacy, identity and norms.

Figures 7 and 8 show the results achieved. For UDC, promoting higher efficacy, identity and norms tends to reduce the carbon emissions, with the higher forced values for norms being the most influential. On the other hand, surprisingly and contrary to the theoretical studies, modifying identity and norms in Aquatim agents lead to a lower decrement in CO_2 emissions than applying only the policy. It is worth saying than Aquatim workers use more public transport than car when going to work, however if they are forced to follow general norms (norms of the society), the behavior is more similar to UDC: the car is the preferred means of transport.

5 Conclusions

In this paper, ABM is used to study the feasibility of different policies that were obtained in backcasting sessions. These models are developed for four different organizations, and follow a common core, paying special attention to the relationships between agents. We have designed two networks working in parallel: a vertical network, representing the hierarchical organogram of the organization, and a horizontal network, reflecting companionship relations. The results of the simulations carried out for two different organizations, UDC and Aquatim, are presented in this paper. Experimental results show that internal motivations of agents, based on actual data of workers, have different influence when applying the same policy in both organizations. The type of social network prevailing in the organization (hierarchical or horizontal) is determinant for the success of a policy, even causing a failure in the adoption of a sustainable behavior, as occurs in Aquatim with the recycling behavior, and in UDC with the reduction of car use.

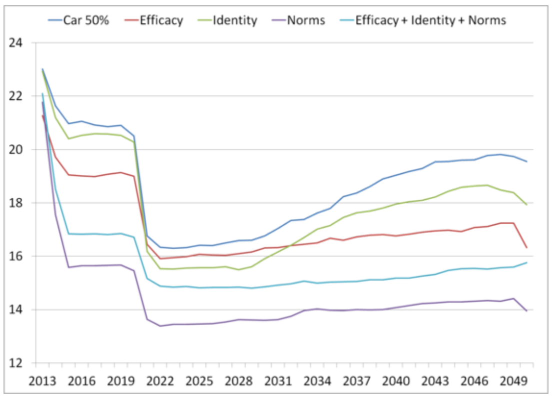


Figure 7: UDC. Comparative study on CO_2 emissions varying internal factors over car reduction policy (CO_2 tons vs date).

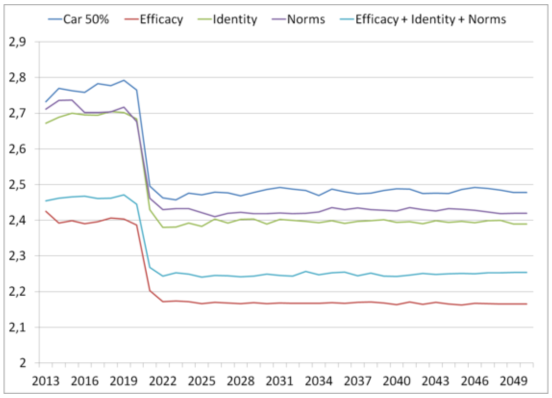


Figure 8: Aquatim. Comparative study on CO_2 emissions varying internal factors over car reduction policy (CO_2 tons vs date).

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