A Multi-Agent Platform to Inform Strategies for Briefing Age-Friendly Communities in Urban China

Liqun Xiang[1[0000-0003-1965-7160]], Geoffrey Shen[1[0000-0002-3111-2019]] and Yongtao Tan[2[0000-0001-7321-4251]]

[1] The Hong Kong Polytechnic University, Hong Kong S.A.R., China
[2] School of Engineering, RMIT University, Melbourne, VIC 3001, Australia
yongtao.tan@rmit.edu.au

Abstract. The World Health Organisation has been working for more than a decade to guide global cities and communities to consider, plan and implement age-friendly places in response to the rapid ageing. In China, promoting age-friendly communities (AFCs) is critical due to the fact of both rapid demographic change and people's increasing awareness of making preparations to deal with their ageing issues. Although many efforts have been made to promote AFCs in urban China, challenges remain during the construction process. The engagement of stakeholders, budget and policy issues always challenge communities' pathways to become age-friendly.

Simulation as a tool of analysis and prediction can be applied to propose constructing strategies and explore solutions regarding the above concerns. For a multi-agent system that contains several agents, an agent itself may lack resources, information and capabilities in solving the whole problem; however, interactions between each identifiable agent provide aggregated attributes, which can facilitate decision-making procedures afterwards.

Therefore, this paper aims to design a multi-agent platform to simulate the briefing stage and explore strategies for promoting AFCs in urban China. The theory and process to develop the platform according to a case study are described; The simulation results and how the platform can help are discussed. This research will serve as a reference for researchers and practitioners to further explore the briefing stage and efficient strategies for promoting AFCs.

Keywords: Multi-agent platform (MAP), Age-friendly community (AFC), Briefing.

1 Background

1.1 Challenges of Promoting AFCs in Urban China

Challenges of promoting AFCs in urban China can be categorised into three aspects, which are the policy considerations, the environment and facility factors, and the market conditions [1, 2].

Developing AFCs has become a significant theme in China's public policy during the past decade. Although it is a breakthrough that only four years were taken for the

'liveable environment' to develop from a theoretical concept to several legal clauses, many issues remain to be tackled when promoting the AFCs. For example, requirements from senior citizens are likely to be overlooked during the infrastructure development process and the provision of social services [1, 3]; Connections between the legal causes and construction strategies are almost blank, which brings difficulties for stakeholders to promote AFCs.

The latest results of the national sampling survey in regard to the living conditions of China's urban and rural older persons indicated that 58.7% of the seniors considered their accommodations insufficiently age-friendly [4]. The lack of facilities limited senior citizens' participation in outdoor activities, caused safety problems to those with limited Activities of Daily Living (ADL) levels and brought pressures to stakeholders engaged in the construction process of AFC projects.

In recent years, real estate projects on housing for seniors in urban areas emphasised more on the wealthy groups' needs, therefore, numerous middle- and low-income senior citizens' needs are likely to be overlooked. Although the investors' investments for promoting such projects, and the customers' payment for purchasing such apartments are quite high, the sales conditions remain optimistic [2]. Such conditions inevitably hinder the process of promoting AFCs that may need longer time to pay back. However, the wealthy seniors account for only a small percentage of the entire ageing group. For the remainder of the senior citizens, the fact is that they become old before getting rich, thereby depriving them of the ability to purchase such apartments and enjoy the related care services.

1.2 Applications of the MAS in Construction Projects

The rise of computation has generated a new field of knowledge named "complex systems". As complex systems show features such like emergence, nonlinearity, decentralization and adaptation [5], the multi-agent system (MAS) has developed rapidly in recent years due to its capacity of dealing with complicated problems regardless the subject area [6]. The most important and special feature of MAS is the agent perspective that takes to view any system as consisting of agents [7]. An agent itself may lack resources, information and capabilities in solving the whole problem, however, interactions between each identifiable agent provide aggregated attributes, which can facilitate decision-making procedures afterwards [8].

Almost all the construction projects contain complex systems since multiple stakeholders work together but generally concentrate on different prioritises. Besides, construction projects have co-evolution of developments and processes by self-modifications: The values of a certain project are set in the initial stages but will keep developing through the whole life cycle [5]. The application of MAS during the briefing stage of AFC projects will give researchers and practitioners a chance to stimulate, identify and analyse issues arising from stakeholders with different backgrounds or belonging to geographically separated teams and working in the dynamic environment.

2 Case Study: Modelling the Process of Stakeholders' Consensus Formation

2.1 Background and Configuration

The target case study community was located in Shanghai and was built in 1994, with most of the original residents grew from their middle-age to old age after 2010. The elderly care facilities are in great need and the investor would like to renovate the original community centre into a small-scale care facility for the seniors. Although residents acknowledged the value of the elderly care facility, they did not want it to be built near their community, regardless changing their original community centre into one [9]. The objections from residents made the project hard to begin. Therefore, an agent-based model is built to simulate and investigate the consensus formation process of residents.

In this study, the networks and the opinions amongst residents are idealised. To apply the agent-based model, assumptions are made on the basis of several opinion dynamic models [10-12]. Considering the total number of households, ageing rate and structure of the owners' committee in the target community, three kinds of agents are set for simulation: (1) A_m: The household that contains a member from the owners' committee; (2) A_s: The household contains at least one member who aged 65 years or over; (3) A_o: The other household. The implemented model can be treated as a multi-state opinion model where agents' initial attitudes are clarified as approval, neutral or disapproval ones, with +1, 0, or -1 to imply the three kinds, respectively; The weight of approval and disapproval are considered more powerful than the neutral ones [13]. During the consensus formation process, agents would make interactions with others and change the initial attitudes according to their neighbours' opinions with a probability related to different influences. Therefore, the attitude of a certain agent is changing on the basis of its neighbours' opinions. The attitude of an agent would not change directly from approval (+1) to disapproval (-1) and vice versa, instead, it will pass a neutral (0) status which indicates a phase of undecided. The simulation results would depict how different initial approval rate and the connections amongst residents, would affect the final opinions of the residents.

2.2 Properties of Agents and Simulation Performed

Apart from holding an attitude, each agent is initialised with two properties: (1) A social impact factor, which is an integer number in the range [0,10], reflecting the agent's social importance. (2) An 'influenceability', which is a random real number in the range [0,1], indicating the possibility that an agent directly changes its opinion to the opposite side without passing through the neutral stance. If the value of this parameter is no less than 0.5, an agent would have the possibility to directly change its opinion. Otherwise, it would pass the neutral status first.

The agent-based model will be run by *NetLogo 6.1.1*, a multi-agent programmable modelling environment that can be applied to explore interactions between agents and the phenomenon emerges as a result of such interactions [14, 15]. **Fig. 1** illustrates the

interface of the simulation model. Two main stages, which are, setup of the initial condition (t=0) and the opinion dynamics (t>0), can describe the simulation performed.

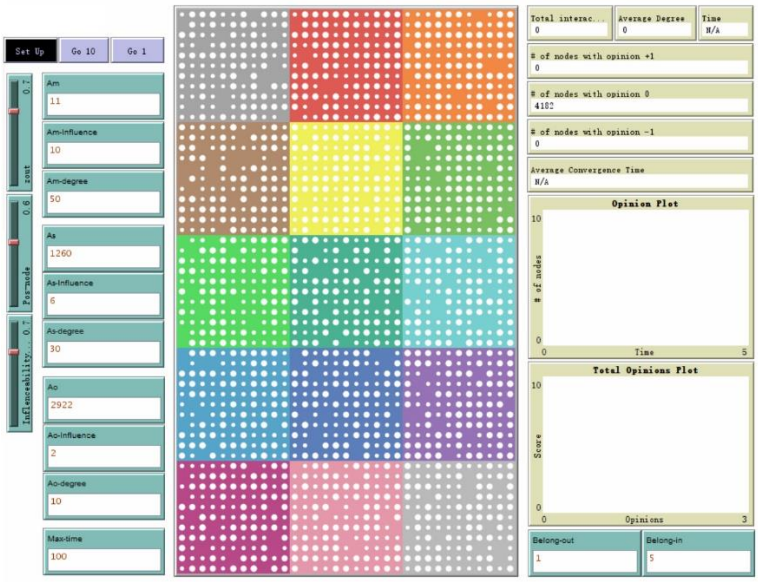

Fig. 1. The interface of the simulation model

Setup of the Initial Condition (t = 0). The masterplan indicates that the target community consists 15 subregions. Therefore, the 4,193 households (agents) are divided into 15 groups, and each group contains approximately 280 agents. The connections amongst agents in each group is built to form the social network. The number of connections that an agent can make depends on the different influence factors. The agents outside the group will have lower impacts on a certain agent than those inside the group. Such assumptions are reasonable since members from the owners' committee are considered as the representatives of other residents and they would be able to contact with more residents, while the seniors spend most of their time in the community and may also get familiar with others. Finally, an opinion is assigned to all the agents when t=0.

Details of the agents' properties are summarised in **Table 1**.

Table 1. Properties of agents for the simulation

Variable	Number of agents	Average connection	Social impact factor
A_m	11	50	10
A_s	1260	30	6
A_o	2922	10	2

The Opinion Dynamics (t > 0). Assuming xi(t) is the opinion of agent i at time t, the opinion of this agent at time t+1 will be a function of both xi(t) and vi(t), where vi(t) is the vector filled with the weighted opinions n(t) of all the neighbours that agent i has connections with [13].

The dynamics of opinions can be represented through the line chart with three curves, with each one represents the change of an opinion. **Fig. 2** illustrates a single event that after struggling amongst three opinions, all the agents reached consensus by the end of the simulation. **Fig. 3** depicts ten events with the same parametres but different random variables setting for simulation. The histogram shows at the end of the given events, the predominant opinion is either consensus or dissent. Both figures indicate that the neutral opinion is only a transition phase.

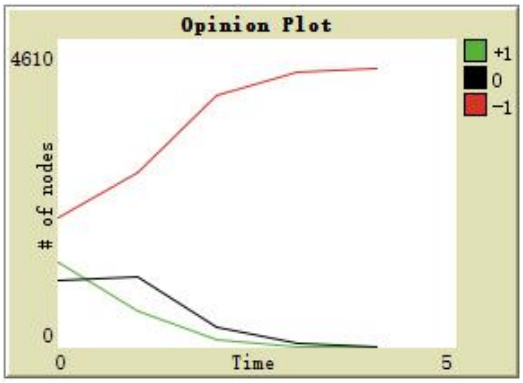

Fig. 2. Opinion plot for a single event

Fig. 3. Distribution of opinions for ten events

Since the simulation aims to discuss how different initial approval rate and the connections amongst agents would affect residents' final opinions, two main parameters can be modified: (1) The initial approval rate, which is the percentage of agents who are in favour of the proposal at the beginning of the simulation; (2) The percentage of

connections an agent makes with those outside the group (Outside connection rate). Both parametres can be changed from 0 to 100%.

It is assumed when the investor proposes a plan of renovating the community centre into a small-scale care facility for the seniors, the initial approval rate is 20%. Since it is realistic that one may have more connections with those who live nearby, the outside-connection rate is also set as 20%, meaning for A_m, A_s and A_o. the connections they make outside the group are 10, 6 and 2, respectively. During the simulation, the two parametres are changed to explore how they would affect the final results.

2.3 Analysis of Results

The authors paid attention to the events when all of the agents held the same opinion in the end. Particularly, the complete consensus (all the opinions equal to +1) or dissent (all the opinions equal to -1) is more meaningful than the neutral one (all the opinions equal to 0).

To clarify the final opinions, a unique parameter *C* (Convergence achieved rate) was calculated to imply the result when the convergence was achieved [13]: E_{+1} and E_{-1} indicate the times when the simulation processes ended with complete consensuses or dissents, respectively, while *E* stands for the total number of events. The simulation ends up with all the opinions equal to 0 is not taken into consideration, since all the residents hold a neutral opinion would not be helpful for the investors to implement their proposal in practice. The value of *C* ranges from -1 to 1, where -1 indicates that all the events were ended with complete dissents, while +1 means such events came to an end with complete consensuses.

$$C = \frac{E_{+1} - E_{-1}}{E} \qquad (1)$$

During the simulation process, a limitation on the time *(t≤100)* was set to exclude the cases when it took too long to reach a convergence. It should be noticed that *C* does not stand for any of the step during the simulation process, it only informs the final status when consensuses or dissents are reached. **Table 2** illustrates the simulation results when *E=10* with the parameter *C* defined above.

Table 2. Simulation results indicating by parameter *C (t≤100)*

Convergence achieved rate *(C)*		Outside connection rate (%)						
		20	30	40	50	60	70	80
Initial approval rate (%)	20	-0.8	-0.4	-0.8	-0.8	-0.6	-0.8	-0.8
	30	-0.1	-0.2	-0.3	-0.7	-0.2*	-0.1	0*
	40	0.3	0.2	0.7	0.2	0*	+1*	-0.2*
	50	0.8	0.8	0.9	0.9	+1*	+1*	0.8*
	60	+1*	+1*	+1*	+1*	+1*	+1*	+1*
	70	+1*	+1*	+1*	+1*	+1*	+1*	+1*

* All the 10 events ended up with either consensuses or dissents

It can be seen from the simulation results that both the initial positive rate and the outside connection rate would influence *C*. To ensure a convergence for each event, the initial positive rate should be no less than 50%, together with an outside connection rate which is no less than 60%. Besides, when the initial positive rate is lower than 40%, even convergences are achieved in the end, the residents are more likely to hold disapproval attitudes towards the investor's proposal. The outside connection rate can be considered as the "weak tie" [16], which is helpful to facilitate the information exchange from different groups. The simulation results indicate that when the outside connection rate is no less than 60%, convergence is more likely to be reached for all the events. With such value equals to 40% or more, chances are even the initial positive rate is lower than 50%, residents would hold complete approval attitudes towards the investor's proposal when the simulation ended.

The average convergence time *(T)* listed in **Table 3** is another parameter that the authors paid attention to. It stands for how many rounds of information exchange happened before the convergence is reached, rather than an exact duration. Since the simulation is conducted with 10 events as a group, when a certain event in the group did not reach convergence before *t=100*, it would be neglected when calculating *T*.

Table 3. Average convergence time *(T)* of the simulation

Average convergence time *(T)*		Outside connection rate (%)						
		20	30	40	50	60	70	80
Initial approval rate (%)	20	3.125	3.667	3.125	3.125	4.000	3.750	4.375
	30	4.200	3.750	3.600	4.286	4.900*	4.667	5.500*
	40	4.286	3.500	3.571	3.750	7.200*	4.400*	5.400*
	50	3.125	3.500	4.556	4.444	4.300*	4.400*	5.700*
	60	3.200*	3.100*	3.300*	3.900*	3.900*	3.600*	3.900*
	70	3.000*	3.000*	3.000*	3.200*	3.400*	3.100*	3.100*

* All the 10 events ended up with either consensuses or dissents

According to **Table 3**, when all the 10 events in a group ended up with convergences, *T* appears to be at least 3.000, with no less than 70% of the agents hold the positive opinion at *t=0*. When the initial approval rate is 40% and the outside connection rate is 60%, *T* peaks at 7.200, meaning more than seven rounds of information exchange are averagely in need to achieve the convergence. Although a higher initial approval rate and a lower outsider connection rate may reduce *T*, three to five rounds of information exchange are still in need before the consensuses or dissents are formed.

3 Discussions

3.1 Implications for Stakeholders of Promoting AFCs

The simulation results obtained from modelling residents' opinion dynamics give the investors implications on facilitating the renovation proposal, mainly by improving both the initial approval rate and the outside connection rate.

The initial approval rate is highly related to residents' concerns. As for the target case study community, the facility that investors intended to promote is an *Embedded Retirement Facility* (ERF) which was gradually emerged from 2014 in mainland China [17]. An ERF is treated as a small-scale, multifunctional community-based care facility with a total construction floor area of no more than 800m^2, service radius not longer than 450m and capacity of no more than 45 beds for senior citizens; An ERF can either offer day respite services, long-term residence or both; ERFs not only assist senior citizens in their daily lives but also help them maintain good health conditions by setting canteens, organising social and recreational activities and providing regular health examinations, amongst others [18, 19]. Therefore, the investors need to communicate with residents, let them know the properties of the facility, so as to eliminate their prejudice and alleviate their concerns with the renovating proposal. Besides, the investors should also consider leaving some places for younger residents to use. Although the community-based care facility for the seniors is in need, younger residents still have the rights to use the community centre, renovating the whole centre without considering their needs is unfair.

Increasing the outside connection rate means to facilitate interactions among residents live in different regions of the community. One potential method is organising activities for the whole community to provide opportunities for residents to exchange information and ideas. It may also be helpful if the investors convince and get support from Am or the As, as they may have more opportunities to interact with others and obtain more social impacts.

The practical experiences of the case confirmed the strategies proposed by the authors: The investors, designers and other constructing group members visited a great number of residents, explained the meaning of renovating the community centre to obtain their supports; Changes were also made regarding the initial proposal and indoor spaces are kept for other residents to conduct physical activities. The effective communication and collaboration amongst stakeholders at the briefing stage ensured the success of promoting the project and provided experiences for similar projects to follow [9].

3.2 Components of the Multi-Agent Platform (MAP)

An agent-based model is formed by three sets of elements in general: (1) the agents, (2) the interactions amongst agents, together with (3) the interactions between agents and the environment [15]. An agent stands for one cluster of stakeholders that engage in promoting AFC projects. According to the [2], seven stakeholders, which are senior citizens (S1), caregivers (S2), government and policymaking institutions (S3), re-

search institutions (S4), project investors and real estate developers (S5), urban planners, architects and interior designers (S6), as well as NGOs (S7), are identified as key stakeholders that would have influences on the construction process of AFC projects in urban China.

The widely accepted and implementable approach to promote AFCs in urban China is inserting or renovating community-based elderly-care facilities in the built regions, during which process three clusters formed by five stakeholders play important roles [19-21]: (1) The end user cluster includes S1 and S2, whose needs should be clarified according to different ADL levels and income conditions. Residents who live in the same community with S1 and S2 also belong to this cluster; (2) The supervision cluster made up by S3, whose applications of the incentive policies would influence choices of S5 regarding promoting AFCs; and (3) The constructing cluster containing S5 and S6, who are responsible for the quality of the constructing work. The above clusters are defined as three agents when designing the MAP, namely the end user agent, the supervision agent, and the constructing agent.

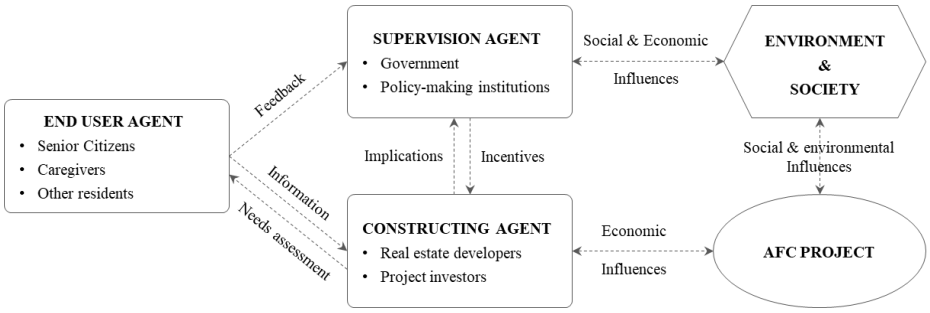

Fig. 4. Relationship amongst agents in promoting AFCs

The relationship amongst three agents during the briefing stage of AFC projects is illustrated in **Fig. 4**. The supervision agent gives the constructing agent policy incentives such like public financial support, tax and land use benefits, and gains implications to adjust policies and regulations [20]. The constructing agent takes responsibilities of figuring out conditions of built communities, assessing needs from the end user agent, and carrying out the strategic and implemental plans. The end user agent is able to provide the constructing agent first-hand information pertaining to their current accommodations and communities, such like whether current service provisions can assist in the daily lives, or whether the barrier-free facilities are adequate to make participations of physical activities possible. In addition, feedback from the end user agent is collected by the supervision agent, particularly after the completion of AFC projects, to evaluate the quality of the work that the constructing agent has done.

Fig. 4 also depicts the influences that the agents would have on the AFC projects, the environment and the society. The constructing agent typically invests in the AFC projects with subsidies from the supervision agent and looks forward to being paid back several years after the completion. Contributions that AFC projects would make

can be clarified both in the environmental and social levels, for the aim of promoting AFCs is to ensure communities as inclusive and equitable places that even the most vulnerable seniors can live in, regardless of others [22]. Even though difficulties usually occur when promoting AFCs projects due to the burdens of resources [23], the government and policy-making institutions as the supervision agent, would gain social and economic benefits from the age-friendly society in the long term.

3.3 The Structure of the MAP

The MAP designed in this study is supposed to help the government and the constructing group to make better decisions during the briefing stage of AFC projects. The platform aims to support users both in the project and in the policy levels: For the project level, suggestions would mainly give to the constructing group regarding how to deal with conflicts between stakeholders; While for the policy level, suggestions are supposed to make for the government regarding the extent that incentives should be given to the constructing group.

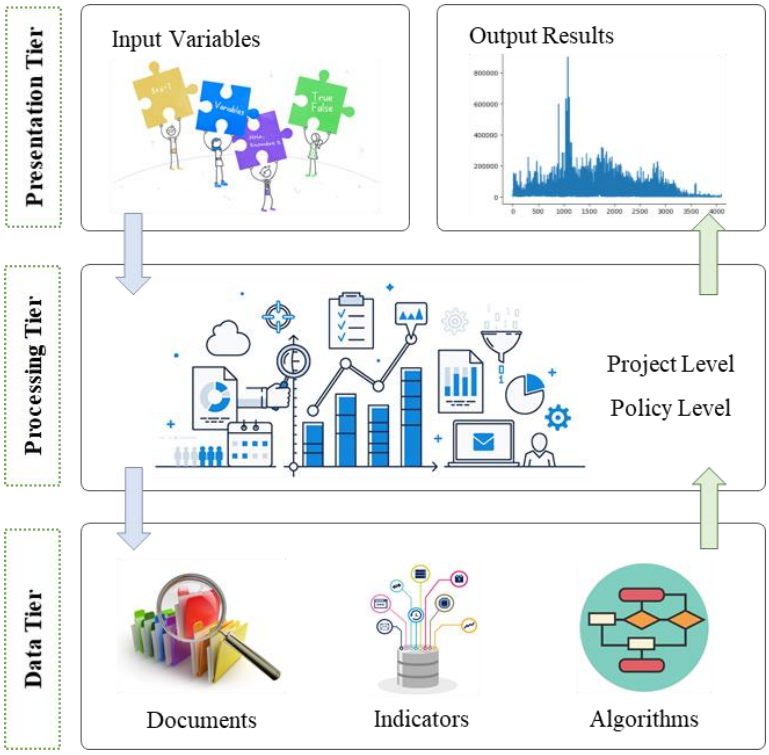

Fig. 5. Three ties of the MAP

The MAP is developed on the basis of the Proactive Construction Management System [24]. **Fig. 5** illustrates the three tiers of this platform: (1) the presentation tier, (2)

the processing tier, and (3) the data tier. The presentation tier is designed for users to set specific scenarios for simulation. The processing layer is where the agent-based model runs within the environment. While the data tier contains general indicators and algorithms that would not change case by case. After the simulation process, results regarding specific scenarios will be displayed through the presentation layer for users to interpret and obtain strategies. **Fig. 6** depicts the potential interface of the MAP where the user logged in as a project investor.

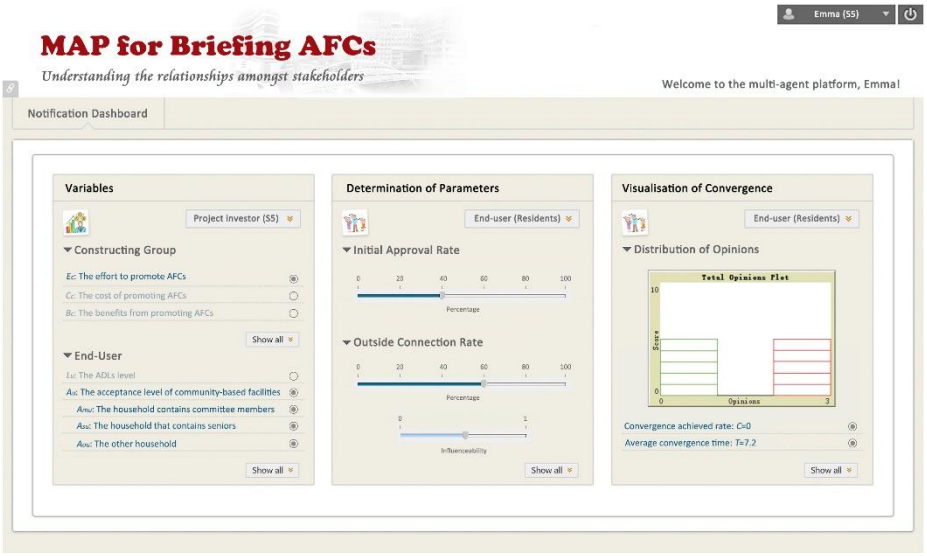

Fig. 6. The interface of the MAP

4 Conclusions

The briefing stage is treated as an indispensable part to promote AFC projects in urban China, during with stage many aspects are needed to be taken into consideration by different stakeholders before setting out the strategic plan. The agent-based simulation of stakeholders' consensuses formation process conducted based on a real case provides the foundation to design a MAP, which would not only help to understand and manage relationships of multiple stakeholders affected by various factors, but to inform strategies during the briefing stage of promoting AFC projects. The components of the three-tier structured MAP are described, the potential interface of the MAP is also illustrated.

For citations of references, we prefer the use of square brackets and consecutive numbers. Citations using labels or the author/year convention are also acceptable. The following bibliography provides a sample reference list with entries for journal articles [1], an LNCS chapter [2], a book [3], proceedings without editors [4], as well as a URL [5].

References

1. Hu, X.: Livable space and building concept of elderly friendly city. Shanghai Urban Management 23(03), 18–23 (2014).
2. Xiang, L., Tan, Y., Jin, X., Shen, G.: Understanding stakeholders' concerns of age-friendly communities at the briefing stage: a preliminary study in urban China. Engineering, Construction and Architectural Management (ahead-of-print), doi: 10.1108/ecam-01-2020-0070 (2020).
3. Wu, X., Qu, J.: China Report of the Development on Livable Environment for the Elderly. Social Science Academic Press, Beijing (2015).
4. Dang, J.: Survey Report on the Living Conditions of China's Urban and Rural Older Persons. Social Sciences Academic Press, Beijing (2018).
5. Son, J., Rojas, E.M., Shin, S-W.: Application of agent-based modeling and simulation to understanding complex management problems in CEM research. Journal of Civil Engineering and Management 21(8), 998–1013 (2015).
6. Liang, X., Shen, G.Q., Bu, S.: Multiagent systems in construction: A ten-year review. Journal of Computing in Civil Engineering 30(6), 04016016 (2016).
7. Macal, C.M.: Everything you need to know about agent-based modelling and simulation. Journal of Simulation 10(2), 144–156 (2016).
8. Motieyan, H., Mesgari, M.S.: An agent-based modeling approach for sustainable urban planning from land use and public transit perspectives. Cities 81, 91–100 (2018).
9. Vanke Weekly, http://www.vankeweekly.com/?p=81189, last accessed 2020/07/16.
10. Hegselmann, R., Krause, U.: Opinion dynamics and bounded confidence models, analysis, and simulation. Journal of Artifical Societies and Social Simulation 5(3), 1–32 (2002).
11. Galam, S.: Minority opinion spreading in random geometry. The European Physical Journal B 25(4), 403–406 (2002).
12. Chen, P., Redner, S.: Consensus formation in multi-state majority and plurality models. Journal of Physics A: Mathematical and General 38(33), 7239–7252 (2005).
13. Le Pira, M., Ignaccolo, M., Inturri, G., Pluchino, A., Rapisarda, A.: Modelling stakeholder participation in transport planning. Case Studies on Transport Policy 4(3), 230–238 (2016).
14. Lu, M., Cheung, C.M., Li, H., Hsu, S.C.: Understanding the relationship between safety investment and safety performance of construction projects through agent-based modeling. Accident Analysis and Prevention 94, 8–17(2016).
15. Wilensky, U., Rand, W.: An introduction to agent-based modeling: Modeling natural, social, and engineered complex systems with NetLogo. MIT Press, Cambridge (2015).
16. Granovetter, M.S.: The strength of weak ties. Social Networks, 347–367 (1977).
17. Hu, H., Wang, Y., Wang, X., Zhang, L.: Situation evaluation and improving path of embedded retirement pattern. Social Security Studies (02), 10–17 (2015).
18. Zhang, S., Zhao, Y.: A study on the design of small care facilities for the elderly embedded in urban communities. Architectural Journal (10), 18–22 (2017).

19. Xiang, L., Yu, A.T.W., Tan, Y., Shan, X., Shen, Q.: Senior citizens' requirements of services provided by community-based care facilities: A China study. Facilities 38(1/2), 52–71 (2020).
20. Li, H., Zheng, H.: Elderly livable environment construction. China Architecture Publishing & Media Co., Ltd., Beijing (2019).
21. Zhou, Y., Li, J.: China report of the development on livable environment for the elderly. Social Science Academic Press, Beijing (2015).
22. WHO Homepage, https://www.who.int/ageing/publications/gnafcc-report-2018/en, last accessed 2020/08/30.
23. Buffel, T., McGarry, P., Phillipson, C., De Donder, L., Dury, S., De Witte, N., Smetcoren, A., Verté, D.: Developing age-friendly cities: Case studies from Brussels and Manchester and implications for policy and practice. Journal of Aging & Social Policy 26(1–2), 52–72 (2014).
24. Li H, Lu M, Chan G, Skitmore M. Proactive training system for safe and efficient precast installation. Automation in Construction 49, 163–174 (2015).