Evaluating and Influencing the Performance of a Collaborative Business Ecosystem – A Simulation Study

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Abstract. In a Collaborative Business Ecosystem, organisations collaborate to acquire and accomplish more innovative and challenging market opportunities. But the sustainability of collaboration requires continuous performance improvement. To this end, well-defined performance indicators can be used to both assess the collaboration level and act as an influence mechanism to induce an improvement in the collaborative behaviour of the participating organisations. By varying the importance (weight) of the adopted set of indicators, it is possible to study the variations in behaviour towards improvement, not only at organisations' level but also at the level of the ecosystem as a whole. In order to assess this hypothesis, this paper contains a case study based on simulation and agent-based modelling whose behaviour is shaped according to actual data on collaboration collected from three companies in the area of the IT industry. Various scenarios are simulated and described.

Keywords: Collaborative networks · Business ecosystem · Performance indicators · Simulation · Agent-Based modelling

1 Introduction

The challenges of dealing with market turbulence, disruptive events, and the increasingly competitive levels induced by globalisation motivate companies to engage in collaborative processes as a way to acquire agility and resilience [1]. This trend is followed by increasing digitalization and supporting technology, providing environments conducive to business collaboration. Moore [2], inspired by natural ecosystems, first introduced the term Business Ecosystem. On the other hand, Camarinha-Matos and Afsarmanesh [3], consider a business ecosystem as a form of a Collaborative Network (CN). As such and aiming to emphasise the collaboration aspect, we have adopted the term Collaborative Business Ecosystem (CBE) [4].

In this context, it is crucial to be able to evaluate the performance of the CBE and the potential gains that organisations can achieve. For the management of individual companies, there are well-defined performance assessment methods and indicators.

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As an example, Kaplan and Norton [5] introduced the balanced scorecard (BSC). This method encompasses key performance indicators aligned with the vision and strategy of companies. Although there is extensive literature research that mentions the benefits of collaboration, only limited contributions to performance assessment in CNs can be found. Some authors have suggested using BSCs in CNs [6, 7], and some approaches have been applied to supply chains (SCs) [8–10]. However, and although they are important contributions, they do not constitute a common line of reasoning to adopt as a strategy for the design of performance indicators for CBEs [3]. Other areas of research identify value creation in collaboration and provide relevant contributions to this topic. As an example, in [11], the authors propose a method to evaluate the alignment of the value systems (VS) of the members of a CN [12]. Other examples propose a variety of methods and metrics to assess the performance of supply chain collaboration (SCC) [13–16]. Finally, the area of social network analysis (SNA), draws insights from the patterns of relationships linking social actors [17], from which metrics tailored to CBEs can be inspired. As another important contribution, we can mention [18, 19], where the authors also inspired by SNA, propose performance indicators for CNs, based on collaboration benefits and to measure social capital.

The purpose of this paper is to present a simulation study to evaluate a CBE through the performance indicators previously proposed [20]. We further aim to be able to change CBE's behaviour through an influence mechanism, varying the weight of the adopted indicators. The study uses the Performance Assessment and Adjustment Model (PAAM) proposed in [21] and tunes it with actual data from three companies in the area of the IT industry. These companies operate in the same ecosystem, two of them being ranked in the FT 1000 – Europe's Fastest Growing Companies 2020 [22]. Organisations in the ecosystem are differentiated into classes of responsiveness that correspond to different profiles. Such classes constrain the evolution of members' behaviour when assessed and influenced by the proposed mechanism. Some readjustment is expected from organisations to improve their behaviour and that of the whole ecosystem. There is a natural tendency (in the same way as individuals) to evolve in the sense that they are evaluated.

The remaining sections are organised as follows: section two presents the simulation model of the CBE, briefly describing the performance assessment and proposing an influence mechanism anchored in theories of inter-organisational networks; section three contains the experimental evaluation, presenting simulation scenarios using actual data from the three organisations considered, as well as a discussion of outcomes; the last section summarises the results, describes ongoing research and identifies future work.

2 A Simulation Model of a CBE

For this simulation study, we adopt the Performance Assessment and Adjustment Model (PAAM) [21] illustrated in Fig. 1. A CBE is characterized by an environment populated by organisations that interact collaborating to accomplish market opportunities. The interactions referred to here as collaboration opportunities (*CoOps*) are

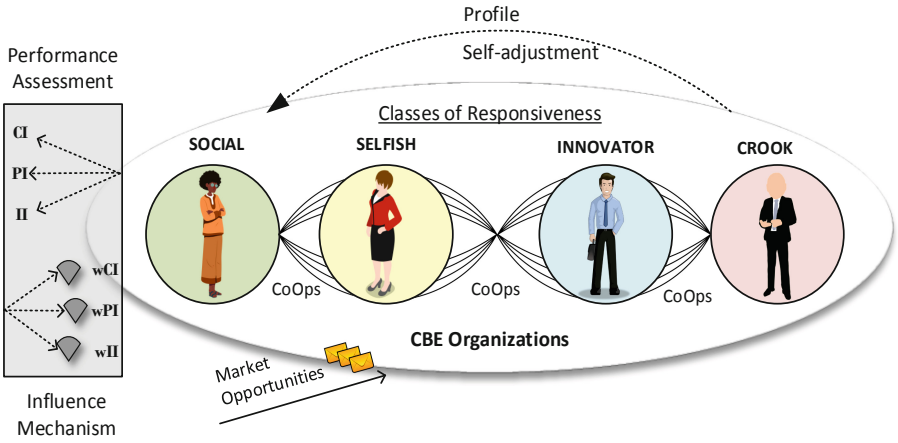


Fig. 1. PAAM (Performance Assessment and Adjustment Model) for a CBE.

represented by "links" between the organisations (the "nodes"), weighted by the number of *CoOps* (*#CoOps*) exchanged over a period of time.

The organisations in the CBE have different profiles, revealing different collaborative behaviours according to the classes of responsiveness considered in Table 1. Each class (i.e. Social, Selfish, Innovator, and Crook) is characterized by three factors (parameterizable decimal values between from 0 and 1), namely contact rate, accept rate, and new products rate, which model the organisation in terms of its propensity to invite other members of the CBE to collaborate, accept invites or tend to accept opportunities involving innovation.

Table 1. Example of parameterization (decimal values between 0 and 1) to characterize the organisations' classes of responsiveness in the PAAM model.

Profiles of Organizations					
Classes of Responsiveness [0..1]		Social	Selfish	Innovator	Crook
Contact rate	Willingness to invite others to collaborate	0,7	0,1	0,7	0,3
Accept rate	Readiness to accept invitations	0,6	0,2	0,8	0,3
New products rate	Tendency to accept opportunities related to innovation	0,2	0,2	0,6	0,3

A "Performance Assessment" system composed of a set of performance indicators (CI – Contribution Indicator, PI – Prestige Indicator and II – Innovation Indicator) proposed in [20, 21], can evaluate the CBE, and also act as a factor of influence by varying the importance (weight) of the adopted indicators by the CBE. This "Influence Mechanism" is likely to induce a readjustment of organizations, thereby improving their profile and that of the CBE.

We use the PAAM model to set different simulation scenarios, varying the number of organisations of each class of responsiveness and, for each of them, also varying the rate of each factor that characterizes it.

2.1 Performance Assessment

For the performance assessment of the CBE, we propose a set of performance indicators mainly inspired on metrics borrowed from SNA [17], more specifically, the application of this area to inter-organisational contexts [23]. Network view of the organisations connected by ties, as well as the strength of ties, has a meaningful influence on its behaviour and performance [23]. In this line, Coleman [24] defines the closure of social networks (direct or indirect links between all the actors) and highlights their importance as a form of social capital. On the other hand, Burt [25] considers the density of a network as a form of closure, since contacts in a dense network (meaning more links) are in close communication. Moreover, Burt [25] also identifies social capital but in terms of brokerage structural holes (weak ties between groups), allowing a competitive advantage for those whose relations cross the holes. Freeman, in [26, 27], also mentioned in Burt [28], proposes the betweenness centrality as a method to assesses the brokerage of these structural holes in the network.

According to predominant research where SNA is applied to inter-organisational contexts, Zaheer et al. [23] identify findings in a three-layer analysis: i) "*dyadic*" (nature of ties) – strong ties among organisations increase trust between them, lowering transaction costs and increasing benefits; ii) "*ego*" (organisations) – high degree centrality is favourably related to their performance, as well as structural holes and closure generate social capital; iii) "the *whole network*" – research focuses on measures such as centrality, density, cliques [29], and small-worlds [30], the findings of which are too extensive to be discussed here, even though there is very little work on business networks [29].

The performance indicators used in this simulation study, briefly described in Table 2, follow the lines of research mentioned above. Based mainly on metrics of density and weighted centrality in SNA [26, 27, 31, 32], are designed to assess individual organisations and the CBE as a whole.

The purpose of this paper is not to discuss the performance indicators which were proposed in earlier works, but rather to apply them to evaluate collaboration in the CBE, and check how they can influence the organisations to improve their behaviour, also resulting in ecosystem improvement.

2.2 Influence Mechanism

The behaviour of a CBE evolves according to some factors that influence the establishment of relationships between the organisations. The inter-organisational relations influence organisational learning and innovation, including organisational change, by promoting or constraining their access to information, physical, financial, and social resources [33]. Ahuja et al. [34] introduced the concept of "*micro-foundations*" as the fundamental drivers of networks at every level of analysis, i.e. the basic factors driving the formation, persistence, dissolution and content of ties in the network. The same

Table 2. Performance Indicators to assess the collaboration of organisations and CBE as a whole.

Performance Indicators	
Contribution Indicator of an Organisation (CI_i) and the CBE (CI_{CBE})	
$CI_i in/out = \frac{C_D(O_i) in/out}{C_D(O^*) in/out} = \frac{\sum_j O_{ij} \#CoOp_{ij} in/out}{\max \sum_j O_{ij} \#CoOp_{ij} in/out}$	Assesses the contribution of organisation O_i in terms of the number of accepted/created (in/out) collaboration opportunities (#CoOp).
$CI_{CBE} in/out = \frac{\sum_i [C_D(O^*) in/out - C_D(O_i) in/out]}{C_D(O^*) in/out * (\#O - 1)}$	Assesses the degree to which the most popular/active organisation [max degree centrality $C_D(O^*)$ in/out] exceeds the contribution of the others.
$CI_{CBE} t = \frac{\sum_i \#CoOp_i}{\#O}$	Ratio of the total number of collaboration opportunities (#CoOp) created/accepted in the CBE by the total number of organisations (#O).
Prestige Indicator of an Organisation (PI_i) and the CBE (PI_{CBE})	
$PI_i = \frac{C_B(O_i)}{C_B(O^*)} = \frac{\sum_k \sum_j O_{kj}(O_i)}{\max \sum_k \sum_j O_{kj}(O_i)}$	Assesses the prominence/influence of organisation O_i in terms of the number of collaboration opportunities (#CoOp).
$PI_{CBE} = \frac{C_B(CBE)}{max C_B(CBE)} = \frac{\sum_i [C_B(O^*) - C_B(O_i)]}{C_B(O^*) * (\#O - 1)}$	Assesses the degree to which the most prominent/influent organisation [max betweenness centrality $C_D(O^*)$] exceeds the contribution of the others.
Innovation Indicator of an Organisation (II_i) and the CBE (II_{CBE})	
$II_i = \frac{\#NewPd_i}{\#PortPd_i}$	Measures the ratio of the number of new products/services/patentes ($NewPd_i$) of the organisation O_i by the total portfolio ($PortPd_i$) created.
$II_{CBE} = \frac{\sum \#NewPd_i}{\sum \#PortPd_i} * r(\#VO, \#NewPd)$	Calculates the ratio of innovation of the organisations in the CBE, weighted by the correlation between the collaboration (participation in Vos) and new products/ services/patents [r(#VO, #NewPd)].

Note: The values of the indicators are normalised between [0..1].

authors [34] identify four primary micro-foundations to explain the genesis and evolution of networks, namely Agency, Opportunity, Inertia, and random and exogenous factors. Moreover, they argue that these micro-foundations operate through "*microdynamics*" to form, dissolve or maintain ties, resulting in the accumulation of changes that affect the structure of the network and are consequently reflected in changes in its "*Structural dimensions*".

Table 3 summarizes the framework of network dynamics of Ahuja et al. [34], describing the four micro-foundations, their microdynamics at the level of node assortativity and tie pattern, and their structural dimensions concerning the ego-network and the whole-network. The authors state that in order to explore the idea of the dynamics of the network, its architecture can be conceived in terms of the nodes that compose it, the ties that connect the nodes, and the patterns that result from those connections. The proposed PAAM model of a CBE is consistent with this view, as it is represented by a network of nodes (the organisations) whose collaboration creates ties (opportunities that they send and receive), forming patterns of connections according to their profile. As such, the micro-foundations of Ahuja et al. are suitable for mapping the different profiles of organizations in the CBE, allowing the design of the proposed influence mechanism, considering, as the authors argue [34], that they determine the evolutionary path of networks at all levels of analysis.

Table 3. A framework of networks dynamics (Source: Ahuja et al. [34]).

Networks Dynamics				
Micro-foundations	Agency	Opportunity	Inertia	Random/ Exogenous
Description	Refers to the focal actor's motivation and ability to shape relationships and create a beneficial connection or dissolve a non-profit relationship, or to shape an advantageous structure	Firms form alliances with firms they have prior alliances with or with the partners of their partners. Both of these emerge from the logic of trust and convenience	Refers to the durability of social structures as well as the social processes through which the actions of the focal actor are influenced, directed and conditioned by institutional norms and pressures	Considers that the emergence of network structures may result from exogenous factors from outside the network or from simple random processes, whether generated inside or outside the network
Microdynamics Nodal assortativity driven	Homophily, heterophily, prominence attraction	Proximity, common goals, common identity	Habits, networking propensity, collaborative expertise	
Tie pattern driven	Brokerage, closure	Transitivity, repetition, referral	Dense clusters with few bridging ties, low connectivity	
Structural dim. Ego-network	Centrality, structural holes, closure			
Whole-network	Degree distribution, connectivity, clustering, density, degree			

Using the framework of Ahuja et al. [34] and based on the network-change behaviour according to the identified micro-foundations and respective microdynamics, we propose an influence mechanism in which the significance (weight) assigned by the CBE Manager to each performance indicator, is expected to influence the behaviour of the organisations. The assumption is that in the same as with individuals, organisations tend to perform according to the way they are evaluated.

As such, we can map the organisations' profiles considered in the simulation model in Fig. 1, into the micro-foundations identified in Ahuja et al. [34] to help to understand changes in their behaviour according to their microdynamics, when influenced by the adopted performance indicators. We can consider the Agency and Opportunity micro-foundations as having a Social profile since both have a propensity to collaborate, nevertheless, Agency is more likely to collaborate with a diversity of organisations (homophily and heterophily) expanding new ties, and those from Opportunity type tend to collaborate with partners they already know and trust (transitivity, repetition, and referral). Moreover, the Agency also has more entrepreneurial behaviour, spanning structural holes (brokerage) to gain benefits from this social capital. From the above, we mapped the Agency with our Innovative profile and the Opportunity with our Social profile. The Selfish profile that can be identified with the Inertia micro-foundation comprises organisations with more conservative behaviour and a low rate of collaboration (low connectivity), due to the propensity to keep the same partners. Finally, the Crook profile can be associated with a collaboration rate due to exogenous and random factors, although these types of factors are also associated with all micro-foundations on a smaller scale [34]. Table 4 describes a possible parameterization of organisations' profile, expressed in terms of their classes of responsiveness.

Table 4. Possible parametrization (decimal values between 0 and 1) of the organisations' classes of responsiveness according to the microdynamics of the mapped micro-foundations.

Profiles of Organisations						
Profiles			**Social**	**Selfish**	**Innovator**	**Crook**
		Micro-foundations	Opportunity	Inertia	Agency	Exogenous/ Random
Classes of Responsiveness	Contact rate	Willingness to invite others to collaborate	0,7	0,1	0,7	n/a
	Accept rate	Readiness to accept invitations	0.6	0,1	0,8	n/a
	New products rate	Tendency to accept opportunities related to innovation	0,2	0,2	0,6	n/a

Considering the characterization of the organisations' classes of responsiveness in Table 4, and a weight defined by the CBE manager to each performance indicator (*wCI*, *wPI*, *wII*) as exemplified in Table 5, the influence mechanism can be set.

Table 5. Example of weights (values between 0 and 5) assigned to performance indicators.

Weights of P. Indicators		
wCI	wPI	wII
4	2	1

Table 6 summarizes the proposed influence mechanism. A given factor of influence (FI%) acts differently in the behaviour of the organisations according to their classes of responsiveness. The weight of each indicator is associated with the attribute of the class of responsiveness for which it has the most significant influence, i.e. the Contact rate is related to the CI, the Accept rate to the PI and the New products rate to the II. As such, the influence on an organisation (O_i) is calculated by increasing its class of responsiveness by a percentage calculated by the factors FI_{wCI}, FI_{wPI}, and FI_{wII}, represented by formulas (1), (2) and (3). A factor ($\pm F_e$) is also considered in the formulas to add an exogenous/random positive or negative influence.

$$contact_{rate}(O_i) + = contact_{rate}(O_i) * wCI * \frac{FI}{wCI + wPI + wII} + F_e \quad (1)$$

$$accept_{rate}(O_i) + = accept_{rate}(O_i) * wPI * \frac{FI}{wCI + wPI + wII} + F_e \quad (2)$$

$$newProduct_{rate}(O_i) + = newProduct_{rate}(O_i) * wII * \frac{FI}{wCI + wPI + wII} + F_e \quad (3)$$

Table 6. Influence mechanism of a Collaborative Business Ecosystem.

Influence Mechanism				
Classes of Responsiveness	**Perf. Indicator**	**Related to**	**Weight**	**Factor of Influence (FI %)**
Contact rate	*CI*	It is related to activity	*wCI*	$FI_{wCI} = wCI * \frac{FI}{wCI + wPI + wII}$
Accept rate	*PI*	It is related to prominence/influence	*wPI*	$FI_{wPI} = wPI * \frac{FI}{wCI + wPI + wII}$
New products rate	*II*	It is related to innovation	*wII*	$FI_{wII} = wII * \frac{FI}{wCI + wPI + wII}$

2.3 Behaviour of the Agents

The simulation model (PAAM) was designed using AnyLogic tools [35]. Accordingly, the CBE is an environment (the business ecosystem) populated by agents (the organisations). The profile of organisations is modelled by probability distributions [35] to simulate their behaviour according to the defined classes of responsiveness. Figure 2 shows a simplified model of a social organisation using agent-based modelling (ABM), statecharts, and system dynamic (SD). The resources of the organisations are maintained in stocks divided into three main groups: *Research&Development*, *Consulting,* and *Inner tasks*. When an organisation receives a new market opportunity (*newMarketOp* composed of a task and number of required resources), it uses a Bernoulli distribution parametrized by the *contactRate* (4) to invite others to collaborate. The recipient organisation uses a Bernoulli distribution parametrized by the *acceptRate* (5) or the *newProductsRate* (6) if the opportunity involves innovation. The higher the parameters, the more likely it is to create collaboration opportunities (*CoOps*), if there are available resources. A triangular distribution is used to generate the number (between a min and max) of business units to distribute to the partners (7).

$$invite_{toCollaborate} = bernoulli(contactRate) \tag{4}$$

$$accept_{collaboration} = bernoulli(acceptRate) \tag{5}$$

$$accept_{collaboration} = bernoulli(newProductsRate) \tag{6}$$

$$businessUnits_{toDistribute} = triangular(minUnits, maxUnits) \tag{7}$$

3 Experimental Results of the Simulation Model

For the experimental evaluation, we parameterized the PAAM simulation model using actual data accrued in 2019 from three companies operating in the same business ecosystem in the area of the IT industry. The data collected includes the resources (number of persons) allocated by function (research and development, consulting and

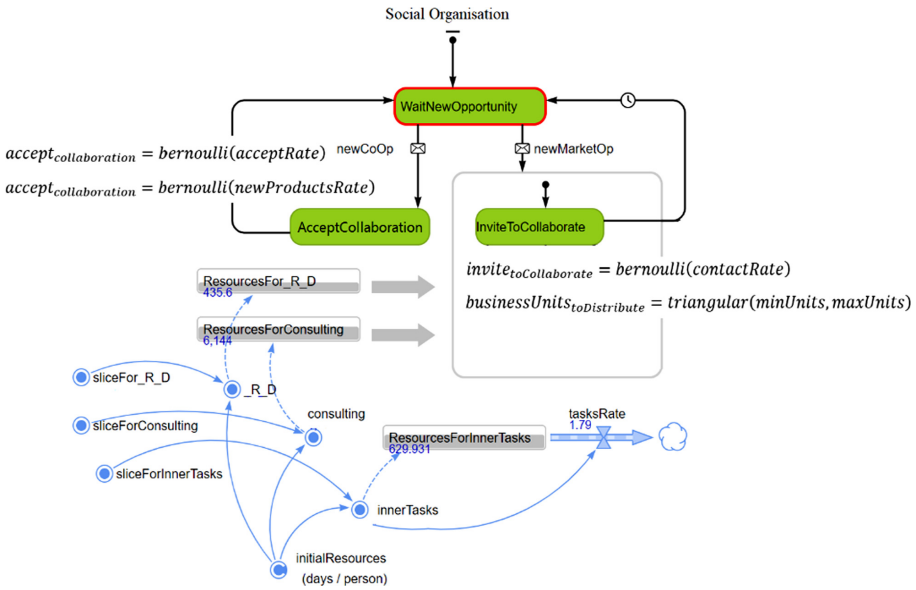


Fig. 2. Simplified model representing the behaviour of a social organisation in the CBE.

inner tasks), number of market opportunities received and accepted (characterised by a minimum, maximum and typical duration in days/person), the partners to whom invitations to collaborate were sent or from whom invitations were received, and the number of products/services created (total, innovative and in collaboration). The data also allowed to estimate the organisations' classes of responsiveness (contact rate, accept rate and new products rate) to configure the behaviour of the agents of different profiles.

Organisation1 is expert in delivering responsive web applications and high fidelity mobile apps, using agile platforms in complex environments and large infrastructures, where they excel in architecture and systems integration. Table 7 shows a sample of data collected from Organisation1 in the year 2019. Organisation2 operates as a consultant and integrator with solutions focused on cybersecurity and networks, providing highly specialized services to government and business markets. Table 8 shows a sample of data collected from Organisation2 in the year 2019. Organisation3 is a system integrator with solutions focused on information management, using the best of breed technologies that best apply to the requirements and objectives of solutions to various market sectors. It also has partnerships with Universities for R&D processes. Table 9 shows a sample of data collected from Organisation3 in the year 2019.

The data of the three organisations are consolidated in Table 10 to parameterize the PAAM model. Here, the attributes of the classes of responsiveness are the average between the minimum and maximum values, where applicable.

Table 7. Sample of data collected in the year 2019 from the Organisation1.

Organisation1						
Resources (persons)	R&D 1		Consulting 46		Inner tasks 15	
Market Opportunities	Received 178	Accepted 136	Duration (days/person) min	mode	max	
Collaboration Ops. Sent	Invites sent min	max	Contact rate min	max	Business units min	max
Partner1	22		0,56		7,2%	
Partner2	23				6,8%	
Partner3	19				6,4%	
Partner4	12				4,0%	
Total	76					
Received	Invites received min	max	Accept rate min		max	
Total	0	0				
Products/ Services	Total portfolio 136		Innovative		New products rate	
	In collaboration 2		min 5	max 9	min 0,04	max 0,07

Table 8. Sample of data collected in the year 2019 from the Organisation2.

Organisation2						
Resources (persons)	R&D 0		Consulting 14		Inner tasks 2	
Market Opportunities	Received 98	Accepted 88	Duration (days/person) min	mode	max	
			0	10	30	
Collaboration Ops. Sent	Invites sent min	max	Contact rate min	max	Business units min	max
Partner5	1	1	0,03	0,08	5,5%	5,5%
Partner6	1	3			5,5%	16,7%
Partner7	1	2			1,7%	3,4%
Partner8	0	1			0,0%	4,7%
Total	3	7				
Received	Invites received min	max	Accept rate min		max	
Partner9	1	2	100%			
Partner10	1	1	100%			
Partner11	1	1	100%			
Total	3	4	1,00			
Products/ Services	Total portfolio 80		Innovative		New products rate	
	In collaboration 3		min 10	max	min 0,13	max

Table 9. Sample of data collected in the year 2019 from the Organisation3.

Organisation3						
Resources	R&D		Consulting		Inner tasks	
(persons)	2		28		3	
Market Opportunities	Received	Accepted	Duration (days/person)			
			min	mode	max	
	27	15	30	60	100	
Collaboration Ops.	Invites sent		Contact rate		Business units	
Sent	min	max	min	max	min	max
Partner12	1	2	0,47	0,73	0,8%	1,7%
Partner10	2	3			3,0%	4,5%
Partner13	1	2			0,4%	0,8%
Partner8	3	4			1,2%	1,7%
Total	7	11				
	Invites received		Accept rate			
Received	min	max	min		max	
Partner12	3	4	70%		80%	
Partner10	2	3	50%		60%	
Partner13	3	4	80%		90%	
Partner8	6	7	90%		100%	
Partner14	8	10	30%		50%	
Partner15	2	3	50%		70%	
Partner16	1	2	100%		100%	
Partner17	2	3	50%		50%	
Partner18	1	2	70%		100%	
Partner19	4	5	30%		50%	
Partner20	1	2	100%		100%	
Total	33	45	0,30		1,00	
Products/ Services	Total portfolio 16		Innovative		New products rate	
	In collaboration		min	max	min	max
	6		10		0,63	

Table 10. Consolidated samples of data from the Organisation1, Organisation2 and Organisation3.

	Organization1	**Organization2**	**Organization3**
Resources	**value**	**value**	**value**
Total (persons)	62	16	33
Total (days/person)	13640	3520	7260
R&D	2%	0%	6%
Consulting	74%	87%	85%
Inner Tasks	24%	13%	9%
Market Opportunities	**min**	**mode**	**max**
Duration (days/person)	0	20	100
Classes of Responsiveness	**value**	**value**	**value**
Contact rate	0,56	0,06	0,60
Accept rate	0,00	1,00	0,65
New products rate	0,06	0,13	0,63
Units to Distribute	**min max**	**min max**	**min max**
	4,0% 7,2%	0% 16,7%	0,4% 4,5%

The PAAM model in Fig. 3, shows a simulation scenario populated by 20 organisations to totalise a similar number of organisations considered in the data samples: 10 organisations with the Organisation1's profile (Social), 4 with the Organisation2's profile (Selfish) and 6 with the Organisation3's profile (Innovator). The model was executed for one year in a simulated environment [35], using the Poisson's distribution [35] to create 2000 market opportunities, plus 20% of opportunities with innovation. The model supports any combination of each profile and any distribution of market opportunities to be possible to create and analyse several simulation scenarios.

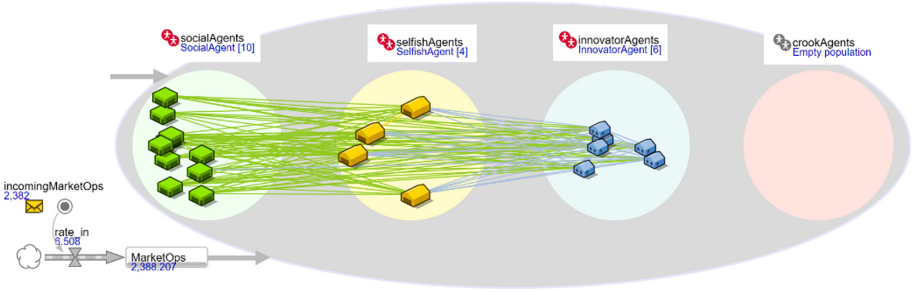


Fig. 3. PAAM set with a simulation scenario using 10 social agents, 4 selfish and 6 innovators.

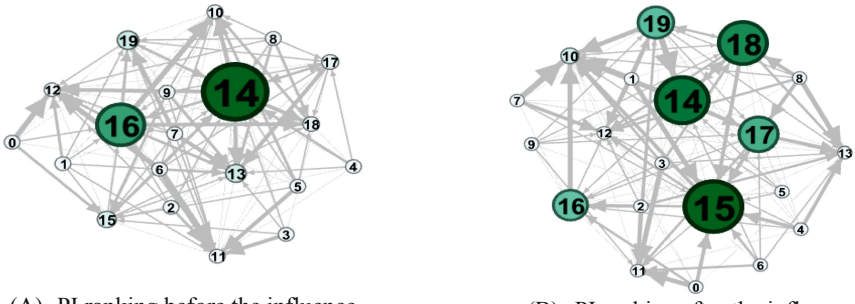
Table 11. Performance indicators CI and PI (normalized) for organisations and the CBE as a whole, before and after applying the influence mechanism.

Performance Assessement before Influence				
Profile	O_i	CI_i in	CI_i out	PI_i
Organisation1 (Social)	0	0,03	0,52	0,00
	1	0,00	0,60	0,00
	2	0,03	0,56	0,00
	3	0,00	0,48	0,00
	4	0,00	0,44	0,00
	5	0,00	0,60	0,00
	6	0,00	0,96	0,00
	7	0,00	0,76	0,00
	8	0,00	0,68	0,00
	9	0,00	0,80	0,00
Organisation2 (Selfish)	10	0,78	0,12	0,00
	11	0,86	0,04	0,00
	12	0,95	0,00	0,00
	13	1,00	0,08	0,10
Organisation3 (Innovator)	14	0,76	1,00	1,00
	15	0,62	0,52	0,06
	16	0,51	0,92	0,66
	17	0,49	0,52	0,02
	18	0,51	0,36	0,02
	19	0,54	0,52	0,11
		CI_{CBE} t = 13,1 CI_{CBE} in = 0,68 CI_{CBE} out = 0,50		PI_{CBE} = 0,90

Performance Assessement after Influence				
Profile	O_i	CI_i in	CI_i out	PI_i
Organisation1 (Social)	0	0,00	0,67	0,00
	1	0,00	0,88	0,00
	2	0,00	0,88	0,00
	3	0,00	0,75	0,00
	4	0,00	0,71	0,00
	5	0,02	0,38	0,00
	6	0,00	0,54	0,00
	7	0,00	0,71	0,00
	8	0,00	0,92	0,00
	9	0,00	0,54	0,00
Organisation2 (Selfish)	10	1,00	0,08	0,08
	11	0,67	0,08	0,00
	12	0,72	0,08	0,00
	13	0,67	0,04	0,00
Organisation3 (Innovator)	14	0,50	0,92	0,89
	15	0,72	0,79	1,00
	16	0,54	0,67	0,47
	17	0,54	0,83	0,58
	18	0,57	0,88	0,78
	19	0,48	1,00	0,50
		CI_{CBE} t = 14,8 CI_{CBE} in = 0,71 CI_{CBE} out = 0,40		PI_{CBE} = 0,79

We can now assess the CBE using the performance indicators, before and after applying the influence mechanism, assuming the weights of the performance indicators defined in the example in Table 5 (*wCI = 2*, *wPI = 4*, *wII = 1*) and a factor of influence FI = 15%. Table 11 displays the results achieved in this CBE before and after being influenced. This assessment does not include performance indicator II, as not enough actual data has been collected in the scope of this paper, to allow its calculation.

Analysing the results in Table 11, we can see that due to the profile of organisations considered as Social, have an Accept rate = 0, the indicators more related to prominence and influence (CI_{in} and PI) are almost all equal to zero. Even after de influence mechanism with a weight *wPI = 4*, the PI indicator remains almost unchanged, which means that an exogenous positive (*+Fe*) factor may have to be applied to reverse this trend. However, using the graphical representation (Ghephy tool [36]) of the network formed by the CBE (Fig. 4), we can perceive the influence of the mechanism, as more organisations gained prestige by acquiring a higher PI. As a result, the PI_{CBE} has improved (lower value) showing a more uniform collaboration in the CBE.



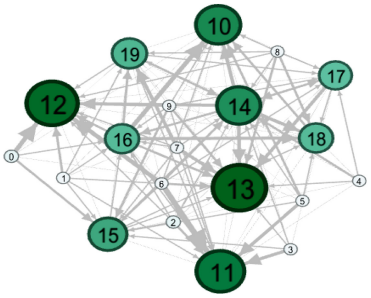
(A) PI ranking before the influence.

(B) PI ranking after the influence.

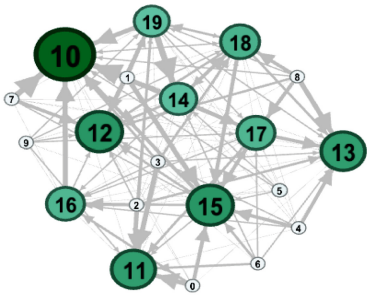
Fig. 4. Shows the PI ranking before (A) and after (B) the CBE was influenced: the nodes' size is related to the PI. i.e., the larger the node, the higher the value of the indicator; the links' strength is weighted by the number of collaboration opportunities exchanged by the organisations.

Regarding the results related to the CI indicator in Table 11, graphically represented in Fig. 5 and Fig. 6, no significant changes can be observed in the contributions of the organisations (CI_{in} and CI_{out}). It is an expected result since the influence mechanism used a low weight *wCI = 2*. However, the CI_{CBE}t has improved, which means more collaboration opportunities created in the CBE. The CI_{CBE}in has increased, signifying more bias in accepted collaboration opportunities, but a levelling out of the created collaboration opportunities in the CBE.

In conclusion, the simulation scenarios presented show that the collaborative behaviour of the organisations in a CBE can be measured by the adequate performance indicators and can be influenced. This approach allows the CBE Manager to orchestrate the network, by varying the weights of the indicators, thus promoting its performance and sustainability. Organisations, in turn, can gain more knowledge and business by engaging in more collaboration opportunities by becoming more influential (scenario of Fig. 4), popular (scenario of Fig. 5), active (scenario of Fig. 6), or innovative.

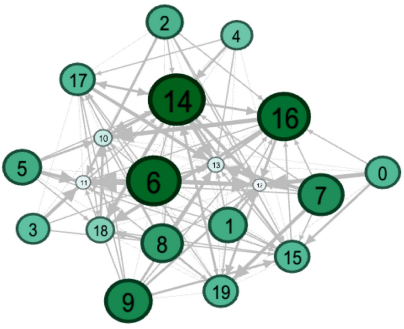


(A) CI_{in} ranking before the influence.

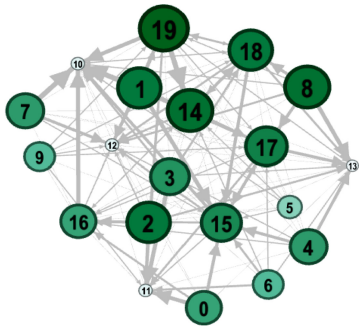


(B) CI_{in} ranking after the influence.

Fig. 5. Shows the CI_{in} ranking before (A) and after (B) the CBE was influenced: the nodes' size is related to the CI_{in}. i.e., the larger the node, the higher the value of the indicator; the links' strength is weighted by the number of collaboration opportunities received by the organisations.



(A) CI_{out} ranking before the influence.



(B) CI_{out} ranking after the influence.

Fig. 6. Shows the CI_{out} ranking before (A) and after (B) the CBE was influenced: the nodes' size is related to the CI_{out}. i.e., the larger the node, the higher the value of the indicator; the links' strength is weighted by the number of collaboration opportunities sent by the organisations.

4 Conclusions and Further Work

The experimental results using the PAAM model showed that it is possible to simulate a CBE populated by organisations, represented by agents, whose behaviour evolves according to different profiles, represented by classes of responsiveness. A performance assessment composed of a set of proposed indicators can evaluate the CBE, and act as an influence mechanism according to the weight of each of the adopted indicators. Several scenarios can be set using any combination of organisations of different profiles. The considered profiles are parametrised and tuned using actual data from organisations in the area of the IT industry to create more realistic scenarios.

The ongoing work is related to the improvement of the simulation model and influence mechanism, introducing exogenous and random factors that can influence positively and negatively the collaboration behaviour of the organisations in the CBE.

Future work includes the inclusion of the Innovation Indicator (II) calculation in the PAAM model and fine-tuning more complete simulation scenarios, to better understand the dynamics of a CBE to induce a better self-adjustment towards an improvement of the organisations and the CBE as a whole.

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