

Simulation of Resource Acquisition by e-Sourcing Clusters Using NetLogo Environment

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Abstract. In the last few years many business clusters have been formed. Thanks to the geographical proximity as well as close cooperation companies are able to gain a lot of benefits that they would not reach if they worked on their own. The ICT¹ has given a possibility to go beyond traditional cooperation and has allowed various geographically spread companies to create alliances. Especially the agent technology seems very promising. The software agents are able to efficiently support e-marketplaces, including partners who offer one another the best cooperation conditions at a given time[1][2]. The main contribution of this paper is a verification of the improved e-sourcing strategy which was presented in [3]. Simulations of this model have been carried out in the *NetLogo* environment. It has been shown that the usage of e-sourcing cluster can inconceivably boost up the process of resource acquisition.

Keywords: agent based simulation, e-sourcing, clusters, logistics, electronic supply chains, NetLogo.

1 Introduction

Procurement is a process of buying raw material, resources, semi-finished and finished products ready for commercial and manufacturing activity and other goods needed for an enterprise to function. The purchasing process is convoluted and requires a lot of laborious activities, such as: creating an offer enquiry, finding a supplier, collecting offers from particular suppliers, choosing an appropriate offer, monitoring orders, paying, etc. Due to this complexity of the purchase process as well as the potential large savings it may allow special attention should be paid to it. An exact identification of the future purchase needs enables to limit the time, prepare the company to finance the purchase in the most profitable way and limit the warehouse costs. In order to reduce the costs of resource acquisition even more competitive enterprises start to cooperate in the purchase process. Together they can achieve better prices than if they were operating individually.

In this paper we are offering to use the e-sourcing cluster (eSoC) concept to acquire resources needed by companies. Before we proceed to presenting the eSoC, however, let us explain what the cluster is, according to the traditional approach.

¹ Information and Communication Technology.

Generally, the cluster can be described as a group or bunch of objects. Merriam-Webster Online Dictionary defines the cluster as a number of similar things that occur together.[4] Cluster applications are multiple. The concept may be found in astrophysics (star cluster), biology and health sciences (cancer cluster), computing (computer cluster), music (tone cluster), economics (business cluster), the military (cluster bomb), etc. This paper focuses on the business cluster. Intuitively the business cluster can be specified as a group of companies which cooperate in order to achieve some advantages.

The term, business cluster, also known as an industry cluster, competitive cluster, or Porterian cluster, was introduced and popularized by Michael Porter in his work, *The Competitive Advantage of Nations*. [5] He defines a cluster as "...a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementariness". [6]

The clusters are formed by enterprises linked through vertical (enterprises connected with others in the relation "supplier-buyer") and horizontal (e.g. competitors creating an alliance to achieve the strategic goal) relationships with the main players located in the same place. The geographical proximity is seen as a way of facilitating the transmission of knowledge, supplies and the development of institutions, which in turn may enhance cluster effectiveness. [7] According to M. Porter, it creates competitive advantages for small and medium enterprises (SMEs) which cooperate and compete closely, since a host of linkages among cluster members results in a whole greater than the sum of its parts. [6] So, all the companies can benefit directly from being part of a cluster.

Unfortunately, clusters understood in this way have some limitations. The definition presented above and many other existing in the professional literature and papers [5][7][8][9][10] suggest that the characteristic feature of the business cluster is the geographical proximity. This vicinity as well as the informal communication and face-to-face contacts connected with it still matter and create the competitive advantage. [11] However, not every enterprise (especially SMEs) can be the member of the business cluster due to a high entry costs. Moreover, it is impossible to physically locate all enterprises in one place. Further, the clusters are formed for years, that is why there is a high exit costs.

The structure of the paper is as follows. In Section 2 e-sourcing, as a modern way of resources acquisition using new ICT, is presented. Section 3 presents the e-sourcing cluster (eSoC) concept and general model of resources acquisition and division using eSoC. Section 4 describes simulation experiment background, variables and constants. Additionally, structure of simulation model implemented in NetLogo environment, numerical results from conducted simulations and trends/dependences analysis are presented. Section 5 concludes the paper and shows future work.

2 E-Sourcing

Geographical proximity still plays an important role in quick information interchange but the emergence of the ICT, especially the Internet, changed this completely. Thanks to ICT, communication costs declined, while trading networks have increased the global market participation of firms not depending on their size, experience,

incomes etc. So, the Internet has revolutionized traditional supply chain management systems and has allowed various geographically spread companies to create alliances and to assist in the purchase of goods and services.[12] The rapid advances in ICT tend to develop virtual links between enterprises contributing towards realizing collaborative relationships with trading partners and easing the virtual sourcing processes, thus clusters do not necessarily have to be locally defined entities. The geographical proximity loses importance because of the easier access to information, yet some valuable, non-codified, but tacit, knowledge can still be exclusively obtained within a cluster.[7][13]

The aforementioned virtual sourcing can be defined as electronic sourcing (e-sourcing) which is the process of finding potential new suppliers using the Internet in general or, more specifically, a B2B internet platforms. The companies using the Internet in the procurement process have an access to a greater number of trading partners and can improve their capabilities in value-added processes. For example, they can acquire resources by participating in e-marketplaces in which they are enabled to find appropriate products or services very quickly.

Information systems that support e-sourcing can be classified into four major segments: buy-side applications, sell-side applications, content applications and e-marketplace applications.[14] The most complex and problematic are the last solutions so we will focus on them in this paper. The e-marketplace platform merges different entities in order to create competitive advantage among suppliers as well as to create access to an abundance of buyers. Although e-marketplaces offer a lot of facilities and have many strengths, there are some limitations of this solutions supporting e-sourcing.

Firstly, today it is very easy to establish a marketplace on the Internet. Thus there are hundreds of globally operating e-marketplaces[15]. This quantity makes it impossible for humans to browse through all of them. Owing to the scope of offers, it is very difficult to sort through all of the information about potential suppliers from many e-marketplaces and to compare one with another in order to make a final decision. Additionally, there are also differences between the requirements of prospective buyers and sellers. The expectations of the former are different from the offers presented by the latter. Moreover, the environment of e-marketplaces is constantly changing – some e-marketplaces appear, some evolve and some disappear. The growing competitiveness and demand changeability make the best offer difficult to find.[3]

3 E-Sourcing Cluster

The task of finding new, reliable suppliers on many e-marketplaces is costly and time-consuming, especially when the company acts alone. Thus, we propose the concept of an e-sourcing cluster - eSoC. The e-sourcing cluster (type of business cluster) is a group of enterprises which are looking for the same type of resource (e.g. steel, plastic, packaging, etc.), so they cooperate in order to acquire it more quickly and more effectively. They communicate and exchange the information automatically using software agents. In such clusters the geographical proximity does not matter at all. Enterprises do not have to be located in one place because they cooperate using the Internet. The eSoC consists of the net of enterprises from the same or similar branch,

which are characterized by the capability of quick and dynamic adaptation to the changing market and different requirements. The eSoC concept can be very attractive to SMEs, because it refutes high entry/exit costs barrier from traditional cluster theory.[16] Another distinctive feature of such clusters is decentralization and the lack of one central point around which enterprises are concentrated.

Within the e-sourcing cluster SMEs can cooperate² with big enterprises which use their size and purchasing power to get cheaper supplies and offer inexpensive goods. The entities joined in eSoC share useful information and knowledge with other members in order to achieve better mutual understanding, acquire wider offers range and develop a base for mutual trust that may eventually lead to collaboration in achieving the members' individual as well as collective goals.[16] Thanks to that, it is easiest to reconfigure elements of sourcing processes according to changing output requirements and the rise of a new market.[17]

Obviously, it must be remembered that in the case of eSoC some transaction costs are higher (e.g. the transportation costs are boosted due to the longer distances), but can be compensated by lower cost of searching and choosing suppliers, contracts management, data interchange, effects of synergy, and, what is most important, lower prices of resource.

In our approach e-sourcing clusters are created on e-marketplaces. All eSoC data is stored within the e-marketplace database. Therefore, e-marketplaces are a base for enterprises to find potential resource/suppliers. E-marketplaces can be accessed by an arbitrary number of software agents (e.g. representing many suppliers) which work independently, or collaborate with others.[2] Main assumption of the model is that e-marketplaces are based on service-oriented architecture (SOA) which provides system interoperability. That means that software agents do not have any problems with migration from one to another e-marketplace. At the same time each e-marketplace is searched only by one enterprise representative (software agent) from each eSoC.

The algorithm of the resource searching and acquisition by e-sourcing cluster in network of e-marketplaces has been presented in detail in work [3]. Let us remember about the most important foundations and assumptions of this model. They are essential to understand the simulation described in the further part of this paper.

First of all, a company creates a profile (equipped with a group of software agents) on one of available e-marketplaces. Then a delegated agents look for sourcing cluster/s. If they do not find it, they create one on each of indicated e-marketplaces. In the next step *leader agents* (type of software agents) of each company assigned to the e-sourcing cluster delegate other, subordinate to them, *scout agents* (another type of software agents) to search for resource with defined conditions (quantity, quality, price, shipping terms, etc.). After that, *scout agents* visit all potential e-marketplaces and look for resources that meet the predefined conditions.

If *scout agent* finds proper resource, it compares resource supply (VRs) with it company's demand (Dm). Than it reserves Rv units of the resource, where Rv value depends on:

- 1) $Dm \geq VRs \Rightarrow Rv = VRs$
- 2) $Dm < VRs \Rightarrow Rv = Dm$.

² Coopetition is a neologism which matches cooperating and competition.

In first scenario only *scout agent* of company acquires the resource. Its demand can be partially ($D_m > V_Rs$) or fully satisfied ($D_m = V_Rs$). If $D_m > V_Rs$ *scout agents* keep looking for next resource offers and its *leader agents* monitor eSoCs' information pool for findings of other agents.

When supply of the resource exceeds demand of *scout agent*, that company satisfies whole demand. Next, *scout agent* comes back to the eSoC from which it originate and informs other agents about the fitness, direction and distance of resource. Than it passes the information to other eSoCs in which it participates. Notifying other agents from all of its clusters about resource results in two main advantages. On the one hand, found resource is almost always used. On the other hand the possibility of resource acquisition should increase, if the company is a member of greater number of e-sourcing clusters. As section 5 will show the upper range of clusters number is not infinite.

In the next step *leader agents* sum individual demands of all, interested in resource, companies in eSoCs and set cluster demand (D) for found resource. Than D is compared with left resource supply ($R = V_{rs} - D_m$). Found resources can be divided in several ways. If total demand of the eSoCs for the resource is lower than or equal to left supply of the resource ($D \leq R$), all *foraging agents* (third type of software agent presented) can migrate to the specified e-marketplace and start the buying process of needed resource. In this case they fulfill all their demands. In the contrary situation, if $D > R$, authors distinguished three groups of resource division methods:

- 1) E-sourcing cluster perspective:
 - a. *First-come, First-buy.*
 - b. *Proportionally.*
- 2) Individual company perspective:
 - a. *On the income basis* – enterprise with the biggest income satisfies its demand first.
 - b. *On the p-level basis* (priority level which can depend on: purchase/sell volume or value, length of e-marketplace participation period, company size, annual income, country of origin, etc.).
- 3) Auction perspective (Vickrey, Dutch, English).

After that *scout agents* visit again potential e-marketplaces and look for the resource that meets the predefined condition. They repeat this process as long as their demands are satisfied.

4 Simulation

In order to check the capabilities of e-sourcing cluster were carried out the simulations of the model in NetLogo environment. NetLogo is a programmable agent based modeling environment for simulating natural and social phenomena. It is the next generation of the series of multi-agent modeling languages that started with *StarLogo*. The environment allows to give instructions to a lot of independent agents which can interact with each other and perform multiple tasks.[18] In NetLogo the turtles (mobile agents)

move on a grid of *patches*, which are also programmable, but static, agents³. All agents can simultaneously carry out their own activities.[19] NetLogo also works on time basis, so changeability of the simulated model over time can be observed and analyzed. Implicitly time in *Netlogo* is measured in *tick* units. *Tick* can represent any possible real time unit (second, hour, day, year, specific time period, etc.).

Two kinds of *breeds* were distinguished: 1) resource offers (*ress*), 2) companies (*coms*). Thanks to that we could define different behaviors and *agentsets* of both breeds. Three kinds of resource fitness were introduced, there were: price (*price*), place (*place*), and shipping time (*ship-time*). Values of each fitness were randomly generated for each individual in each breed.

The fitness of sought after resource was compared with the fitness of found one according to the rules:

- 1) *Price* of found resource cannot exceed *price* declared by the company.
- 2) *Place* of found resource must be the same as region of company.
- 3) *Ship-time* of found resource cannot exceed *ship-time* declared by the company.

It is worth noticing that sellers give different prices, some of which include other additional costs, but others do not. A lower price is offset by significantly higher acquisition costs such as those of delivery, monitoring, coordination and other administrative tasks.[20][21] Thus it is very difficult to compare them with one another. In our model *price* comprised all those costs.

The basic number of potential e-marketplaces was assumed to be 900⁴, but for additional comparison and model verification simulations with 9000 e-marketplaces were carried out. E-marketplaces are represented by *patches*. Other parameters, which were constant, are as follows:

- *Cnum* = 100 – initial number of companies.
- *Rnum* = 10 – initial number of resources.
- *Max-cval* = 20 – maximum value of company demand.
- *Max-rval* = 200 – maximum value of finding resources.
- *Max-res-life* = 500 – maximum resource life.
- *Max-ship-weeks* = 1 – maximum randomization of number of shipping weeks.

The most significant variable is *max-clu-num* (maximum clusters number), which was assumed to vary from 0 to 20 and its influence on companies demand satisfaction is the main experiment measurement. Participation in a cluster is based on probability (in this case probability is 50%), which is set individually for each company's cluster. Additional important assumptions for this simulation are:

- Method of new resources generation: every 100 ticks random *rnum*. resources are generated - from 0 to 9 resources.

³ In NetLogo there are four types of agents: turtles, patches, links, and the observer.

⁴ eMarket Services (<http://www.emarketservices.com>) has about 600 e-marketplaces in its database. Authors increased this value by 50% in connection with internet based B2B solutions popularization.

- Relation between $cnum$ and $rnum$ – 10:1.
- Relation between $max-cval$ and $max-rval$ – 1:10.
- *Scout agents* only chooses resources that can satisfy their company's demand (fitness of found resource/s must meet *price*, *place* and *ship-time* rules presented above).
- Method of resource/s division is *First-come, First-buy*.

The simulation was run 1000 times for each case (changing $max-clu-num$ value by 1), that gives 21000 simulations. Additionally, each case (static value of $max-clu-num$,

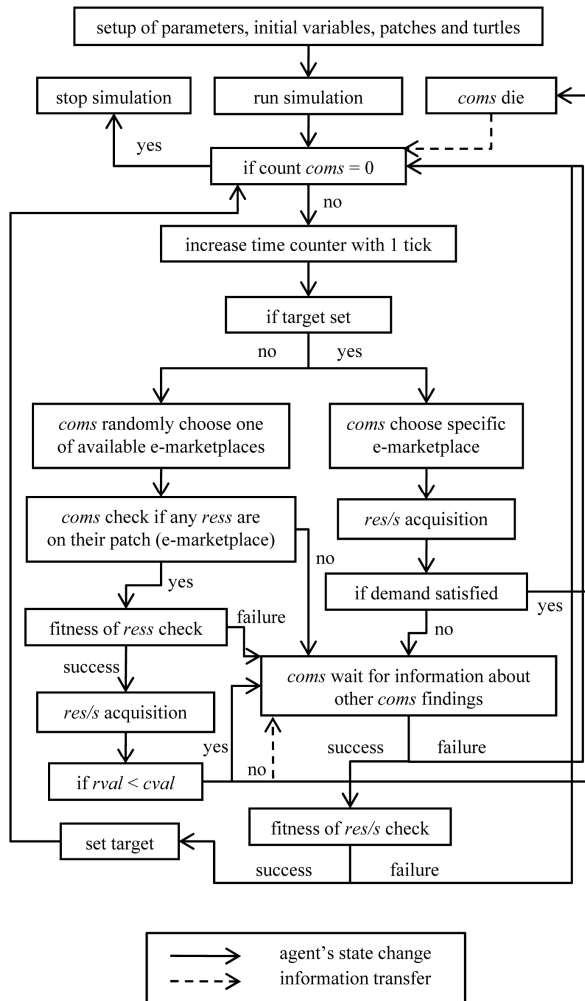


Fig. 1. NetLogo simulation algorithm of eSoC model

Table 1. Time (ticks) after demand of specific percent of companies was fulfilled (900 e-marketplaces)

Clusters	100	90	80	70	60	50	40	30	20	10
0	5704	1882	1193	873	660	509	387	292	195	102
1	4980	1496	933	665	517	400	305	224	147	75
5	3786	749	465	321	225	164	115	74	45	22
10	2850	461	312	222	155	107	73	47	27	15
20	2086	382	239	171	123	84	57	40	25	12

i.e. 5) was examined ten times (each 10% of *cnum* decrease) to get better view of *cnum* changeability over time (ticks). When we add cases with 9000 e-marketplaces, it will give us total number of 420000 simulations in eSoC experiment.

Figure 1 shows structure of simulation model implemented in NetLogo. Solid lines shows change of agent’s state and dashed ones illustrates only information passing.

Simulation results were compared for 900 and 9000 e-marketplaces scenarios. Numbers presented in table 1 shows numerical data from five cases of the experiment: no clusters, one, five, ten, twenty potential cluster/s. Analysis shows that increasing number of e-marketplaces ten times (to 9000) increases time of population demand satisfaction also about ten times. It can lead to first conclusion from experiment, that time of population demand satisfaction is directly proportional to number of e-marketplaces. Of course this conclusion is true when we have got the same initial parameters of the simulation as well as methods of interactions and dynamic model evolution.

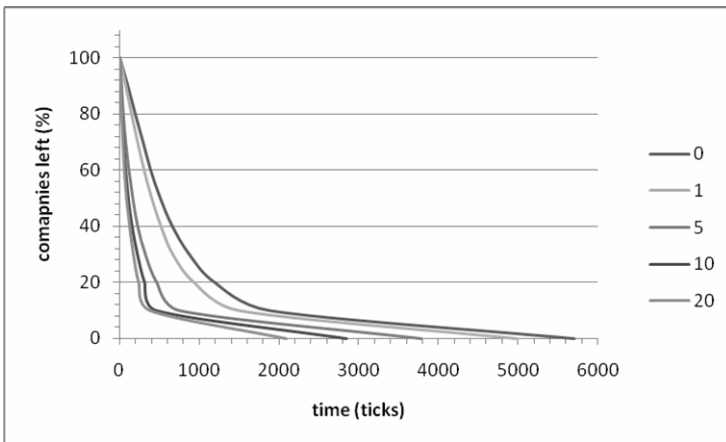


Fig. 2. Population demand satisfaction over time dependent on maximum number of clusters in which one company can participate. Legend shows maximum number of potential clusters.

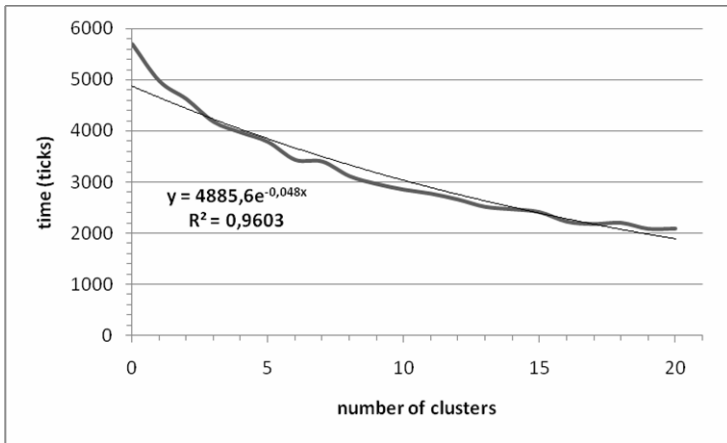


Fig. 3. Total population demand satisfaction time dependent on maximum number of potential e-sourcing clusters

Another conclusion is that increasing maximum number of potential clusters (eSoCs) do not decrease time of population demand satisfaction proportionally. As figure 2 shows differences between 10 and 20 *max-clu-num* are marginal. It corroborates the Gossen's First Law also known as the law of diminishing marginal utility. Additionally, when entry and stay in cluster costs will be taken into consideration, it can be stated that for this particular resource model maximum value of *max-clu-num* is 10.

Other analysis of the experiment is comparison of total population demand satisfaction time and maximum number of potential e-sourcing clusters. Figure 3 shows that increasing *max-clu-num* influences on total population demand satisfaction time and decreases it on specific trend basis (96% trend fit).

5 Conclusions

The experiment shows that eSoC model can significantly boost company's resources acquisition process. Additionally, lower than traditional Porterian cluster entry/exit costs can indirectly result in a lower risk factor of investing in a new business model. While this can lead to better cooperation, cross-companies relations and collaboration in achieving the eSoC's members' individual as well as collective goals.

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