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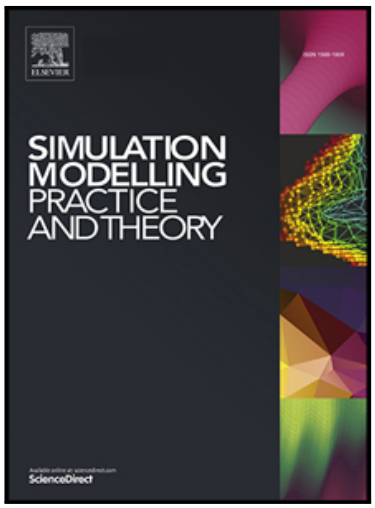

An Agent Based Modeling approach in the Strategic Human Resource Management, including endogenous and exogenous factors

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An Agent Based Modeling approach in the Strategic Human Resource Management, including endogenous and exogenous factors

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Abstract

Human Resource (HR) takes a dominate place in the life of an organization knowing that it becomes one of the competitive factors, it is also considered an important preoccupation of governments who try to control the wage bill and the HR structure evolution. The current trend in HRM is to enhance it to the strategic level.

The HR field is a complex system, its management is affected by the HR behavior in the way that it is very tough to predict or analyze the preferences and decisions of an employee; HRM is a dynamic discipline highly linked with people behavior, which interact freely without anyone's guidance. This analysis named bottom-up starts by focusing on the characteristics of each agent at a micro-level, because the agents behaviors and interactions each other and with the external environment lead to new laws and changes that occur on the macro-level.

For this reason an Agent Based Modeling (ABM) is proposed in this paper to integrate this property (behaviorism) in modeling the HR structure evolution. This approach takes into consideration the endogenous conditions of an employee in his work and the exogenous shocks that can affect his behavior; the goal is to get closer to the HRM aspects reality and predict the future patterns of the HR structure.

Keywords: SHRM, Bottom-up, ABM, Behaviorism, Emergence, Structure evolution.

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1. Introduction

First we begin by defining what a strategy is. In sample words, strategy is defining what we want to do and how we intend to do it. Armstrong [1] has defined it as a declaration of intent which concerns longer term goals; it is more concerned with how those goals should be achieved. Strategy has been defined in other ways by the many writers on this subject, for example Richardson and Thompson [2] emphasized that a strategy must have strategic objectives and a plan of action.

For decades organisations wait from their HRM practices just to meet the short term requirements of their missions, now with the entering of the SHRM in the schedule of the decision makers, organizations are better able to respond to the demand of their internal and external environment. For now on SHRM is a part of the process of strategies formulation [3].

It is well known now the relationship between HRM practices and innovation [4]. In the same context Amarakoon et al [5] studied how such innovations support competitive advantage. Pinnamaneni et al [6] argued that HR development potential should be considered from the initial formulation of the corporate strategy, not only during its implementation to gain competitive advantage.

The structure of this paper is organized as follows: first, we provide an overview of the main concepts of SHRM and complexity of the HR system, and then we present an overview also of the ABM that helps in the analysis of human behaviours from the micro level and shows the emergence of new patterns. Next, we try to present a new framework of the whole population of employees as a HR system to be modeled with an agent based approach followed by a numerical example.

2. Strategic management process

The strategy plan determines organizational purposes and objectives, and also the way and resources to achieve it. According to Wayne and Martocchio [7] there are four steps to formulate a strategy, (Fig 1), beginning by deciding what is the general purpose of the organization. Environment assessment concerns on the one hand evaluating internal strengths and weaknesses, on the other hand predicting external opportunities and threats. The essential objectives have to be determined in order to enlighten general orientations. The final step is assigning a strategy to each objective and specifying how to achieve it. Belhaj and Tkiouat [8]

have proposed frameworks for the SHRM that emphasise on the above steps and also on the quantitative and qualitative data.

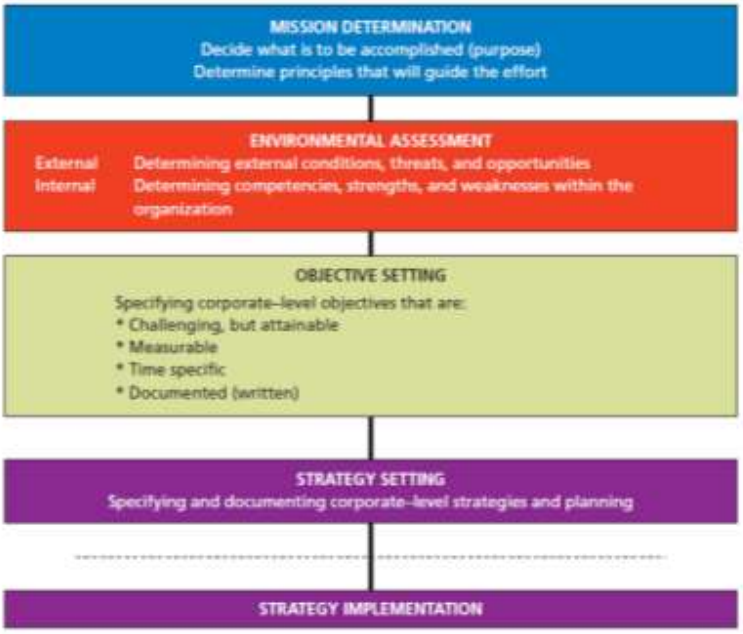

Figure 1. Strategic management process. (Wayne and Martocchio [7])

3. Implementing the SHRM

Authors have proposed frameworks to build a SHRM formulation beginning with the strategic planning and well analysed data, these are relying on:

- Quantitative information coming from the gap analysis using Markov modeling (for example) [9].

- Qualitative information using SWOT analysis coupled to Fuzzy method to refine the strategy choice [10].

SHRM has taken recently a big importance both in the field of HRM and in the field of strategic management. Miles and Snow [11] viewed that HRM is the key factor in implementing business strategies; in that sense it must be enhanced to the longer term management level. Crispin et al [12] made light on the fact that implementing SHRM can have a positive result on employee's performance.

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It is time to switch up from the traditional management of HR to a modern and scientific approach that can enable us to manage strategically. Complexity of the HR system drives us to emphasize on the importance of integrating scientific tools like the ABM in the strategic human resource formulation. It is with reliable data and well analysed information that a strategy can be built.

4. Theory of complex systems

The theory of complex systems has been the subject of much research since 1980s when scientists have noticed the presence of complex systems in many sides in life especially with the technological development. Now a question of how to deal with such systems arises to avoid the many risks that can happen from bad analysis and forecasting [13].

It is also in the 1980s that substantial progress has been made in understanding complex systems using a combination of basic theory, much of it derived from physics, and computer simulation [14].

Social systems, a kind of complex systems

Social systems are complex because they are composed of many different agents involved in mutual interactions, and interactions with their environment. The complex systems approach of real social systems consists of this transition from the local to the global and in particular to the understanding of organizational processes and norms of behavior .it is true that these systems can be complicated at the individual level but they are descriptible at a more global level.

HR systems, a complex social system

There are systems for which evolution is not anticipated and tend to be more reactive because of the existence of non-deterministic arising events; these complications require the implementation of the needing strategies to make the necessary decisions. It is also stressed that the complexities of social systems, here the HRM systems require new methods to prevent shortfall or surpluses in the future [15].

HRM is becoming a complex system because of the multitude of relationships between the resources, its behavior require human interactions. In this dynamic environment can occur

some not anticipated variations due to non-deterministic arising events that need suitable strategies [15].

HR system is a complex social system and complexity is due to:

- Large number of agents involved in local interactions;
- Information can take the two directions from the managers to employees or vice – versa;
- The bottom-up procedures leads to emerging patterns;
- Uncertain invasive behavior;
- Potential existence of multiple equilibriums;

From what precedes it appears clearly that the HR field is a complex social system by nature and complexity lies in its unpredictable behavior.

The modeling used here favors the bottom-up approach because the future situation of the HR will emerge from interactions within a population of agents, following this method the employees are seen as a complex dynamic system. They are represented by agents that evolve and interact in an artificial world. Goudet and Kant [16] stated also that from the analysis of micro and macro levels will emergence new laws. ABM approach is suggested to study complex social systems that are highly depending on human behavior.

5. What is an agent

Poole and Mackworth [17] defined an agent as an active entity in a particular environment acting and reacting to changes and aware of the emerging events. On another hand Wang and Wang [18] stated that besides the capabilities and knowledge (or beliefs) about its environment the agent performs actions in order to achieve a set of goals.

According to Macal and North [19] agents have certain characteristics (Fig 2):

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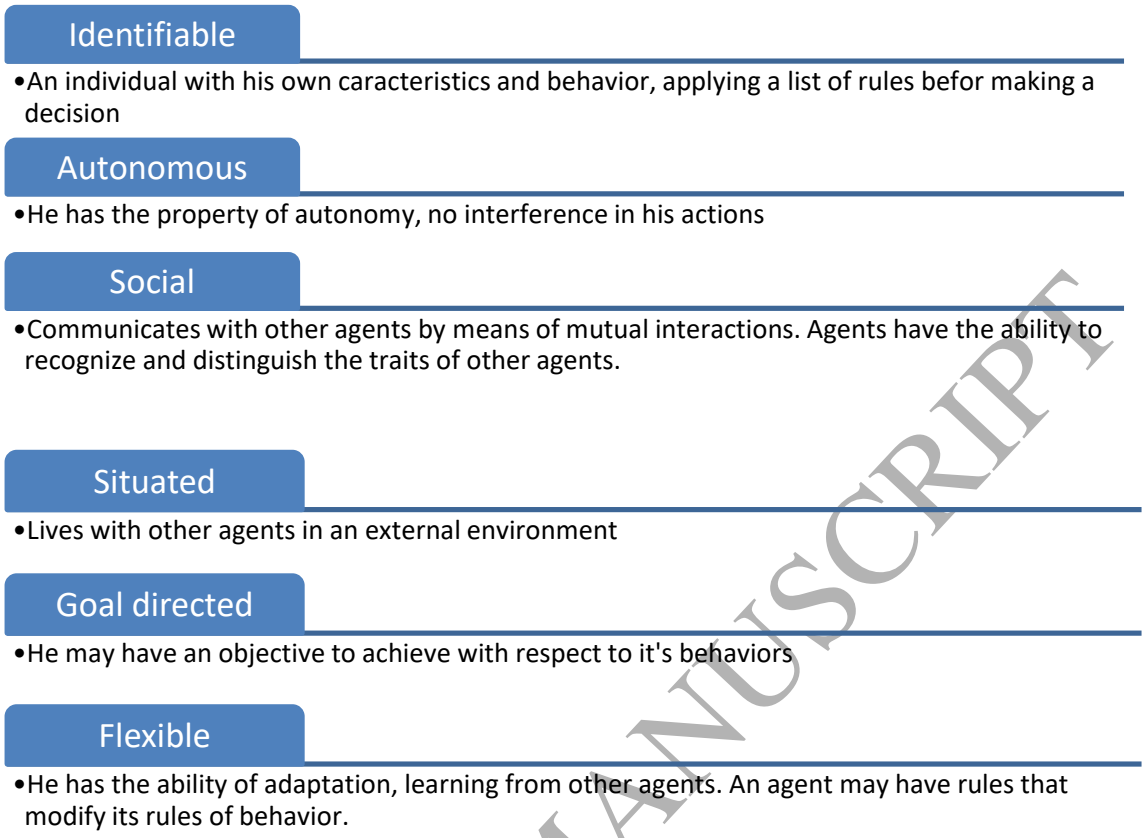

Figure 2. Agent's characteristics. (Adapted from Macal and North, [19])

Agents are linked to each other through rules that are often simple, each agent sends a kind of a message or stimuli which are received by the other agents and the environment, these rules are evolutionary according to the experience of the agents [13].

Many authors emphasize on the specific properties of the agents. They include [20,21,17].

6. ABM defined

ABM is a method to simulate the evolution of a system that is composed of variety of components that interact with each other which we call agents. This method has known a big boost because of the development of computerized decision support systems and intelligent computational programs [22].

The scheme of an ABM is constituted by agents and the environment where they evolve; there are interactions that can occur between:

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- Agent-agent

- Agent-environment

The multitude of agents makes the system complex.

ABM is a bottom-up modeling in the sense that the regularities of the HR system will emerge from the interactions within the interacting families that are considered heterogeneous, at each step, the agents adapt their behavior according to their new state and changes in the environment [16].

7. Agent based modeling to model complexity

Agent based modeling in Sciences

The first ABM social models were developed by Sakoda [23] called the checkerboard model; it was an inspiration of the cellular automation. Gilbert and Troitzsch [24] have done similitude of social processes to a group of people where agent relationships represent the process of social interaction. The same idea of the social interaction mechanisms was treated by Epstein [25] who demonstrated that an emergent cooperative behavior can take place from the individual or group interaction [22].

The last decades have known the availability of a huge amount of data of all scientific branches, the knowledge about our world is growing fast as well as the rise of computational tools, and scientists are now daily gathering data and observing different phenomenon [26]. ABM is the suitable tool to deal with this abundant data that makes our world very complex [27].

According to Wilensky and Rand [27] ABM is the suitable tool to understand complex systems; especially social systems; the reason behind this is that the ontology of ABM is similar to the real world around us, though it is possible to describe complex processes in a naturalistic ways, (Fig 3) :

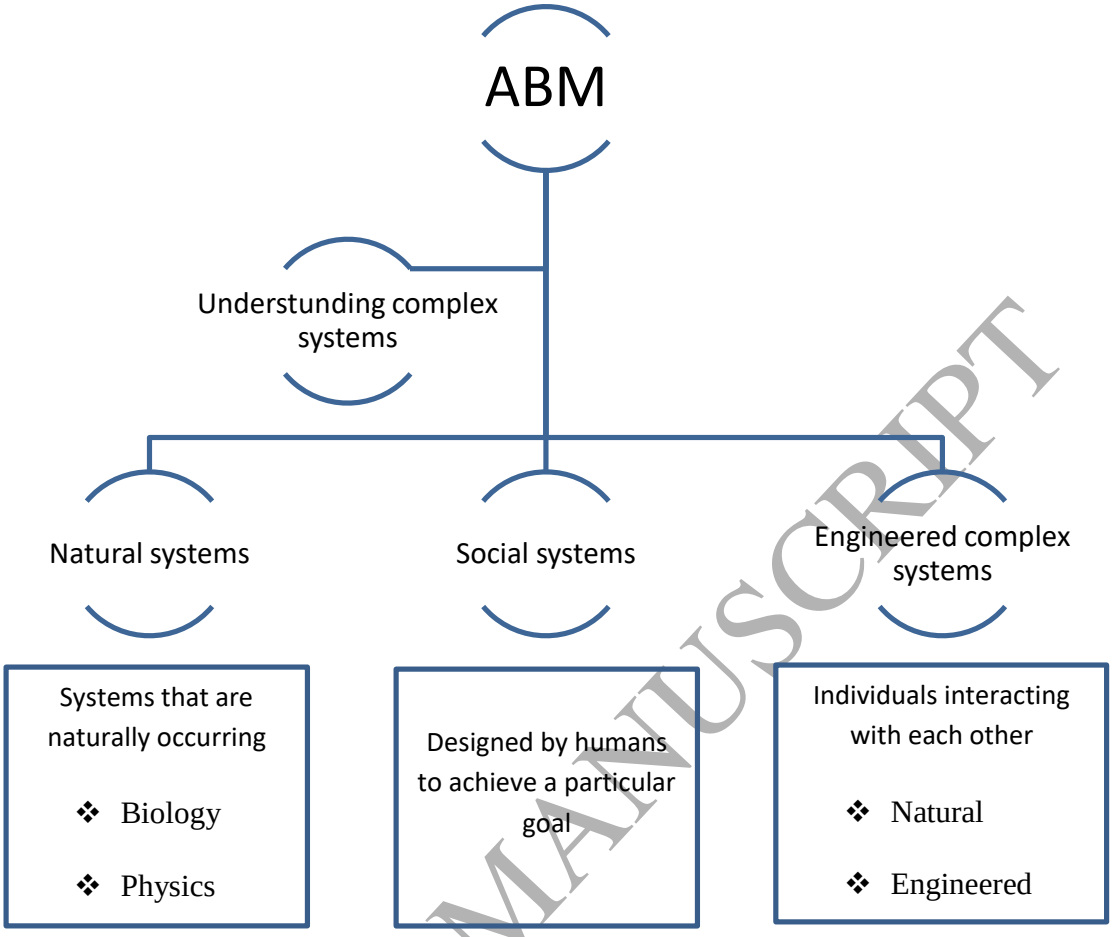

Figure 3. The complex systems described by an ABM (Adapted from Wilensky and Rand [27])

Emergence and emergent phenomenon

Emergence is the most important property of ABM. It is a phenomenon that appears at the macro level that reveals a certain behavior of the system which is not encoded at a micro level and it is often generated by simple rules; the cleverness in building ABM is to find emergence by experiencing the appropriate rules that can generate the phenomenon [27].

Emergence is not planned or directed by an authority that would have an overview of the system, it occurs from the process of the interactions between agents, these phenomenon's are often surprising and defy intuition [13].

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Netlogo, a tool of computation

Netlogo is a programming language software; it is well suited to the multi-agent systems and complex natural and social phenomenon. It models agents that are evolving overtime and interacting with each other and with the external environment. The goal is to discover unpredictable patterns that can emerge from the micro level behavior of agents [28].

Netlogo is a free ABM environment that was developed by [29] at Northwestern University's center for connected learning and computer-Based modeling (http://ccl.northwestern.edu/netlogo/).

Related works

Researches applying Agent-based modeling in the HR system are scarce; Passos et al [30] used an ABM to study a HR cycle; the model was adapted from the original one proposed earlier by Passos et al [31] and inspired from the aging chain model where there is a delay that results in more time spent to employee to be promoted from beginner to more experienced positions. There is also another delay for the employee to pass from the last employee stage, master, to finish his career at the company. The aging chains model proposed by Sterman [32] in the book "business dynamics: systems thinking and modeling for a complex world" can be used to represent this cycle, and show employees evolution.

Belhaj et al [33] have proposed an example of the agent based modeling applied to the HRM that is represented as a system of agents that evolve automatically and freely, it appears that the employees' conditions in the work and the administration policy can lead to an emerging behavior

Castro and Parsons [34] treated the problem of human preferences in decisions under risk by proposing an agent model based on an extension of Prospect Theory (PT) called Smooth Prospect Theory (SPT).

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8. Application of ABM in the HRM

The use of the ABM in the HRM field is justified by the complexity of the HR system and also by unpredictable behavior of employees regarding internal and external factors; the objective of utilizing the ABM in this example is to:

- Follow the HR structure evolution in terms of numbers in order to prevent a shortfall or a surplus;
- Follow the evolution in terms of the cost in order to prevent the wage bill;
- Forecast the annual average number of departures;
- Forecast the annual average number of employees in each family of grades;
- Prevent the effect of endogenous and exogenous factors on HR structure evolution;

The HRM process steps adopted in the framework

The career path of an employee is composed of four big steps, after the recruitment an employee aspires to an evolution in his grade and level and so wait to be promoted to a higher position. In his career an employee can decide to quit his job to demand a transfer or an early departure or he can change his job due to unsatisfaction and finally comes the time of retirement. The following figure; (Fig 4) illustrates a general life cycle of an employee.

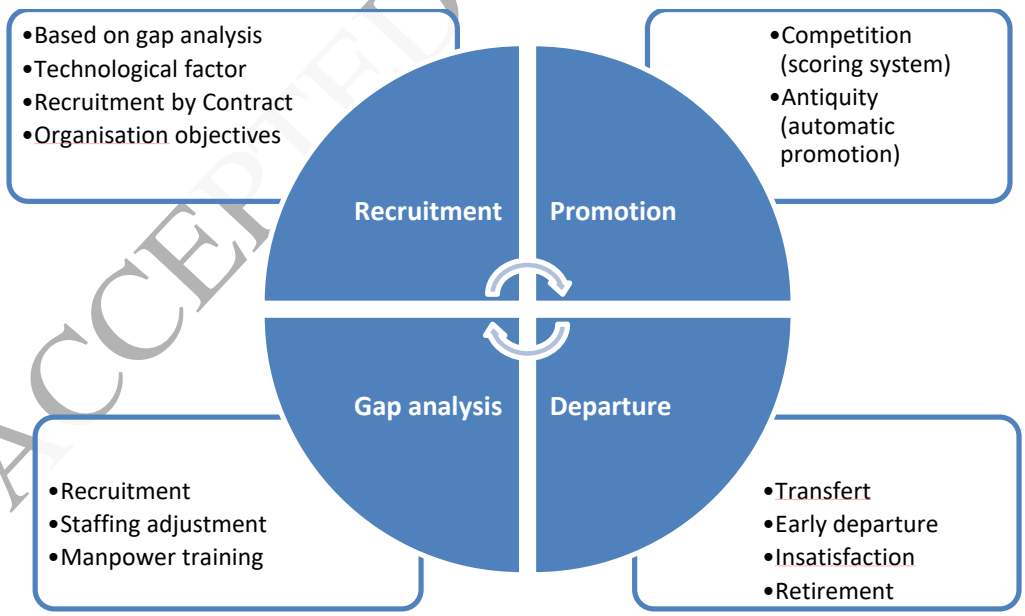

Figure 4. The employee career steps (Authors)

The studied structure is a public administration constituted of 5600 employees; we choose to begin with an initial structure randomly, taking into consideration the limitations of numbers and age in each family. The interval age for our population of employees depends on each family; it is taken between 20 and 63 years [33].

For the first grade in the administrative agents' family the age interval begins by 20 years, unlike administrators or engineers families where the minimum age is 25 years. These minimum ages are in reality the time for each employee to obtain the correspondent degree.

The starting structure is composed of:

- 25% of administrative agents;
- 19% of technicians;
- 46% of administrators;
- 10% of engineers;

The simulation time horizon is 50 periods. The employee behavior is taken into consideration through the endogenous (endo) and exogenous (exo) factors to simulate their effect on the simulation.

The parametrable variables

There are parameters showed in the interface user that can be changed in accordance with the studied case:

- ✓ The initial number employees ;
- ✓ The starting structure decomposition ;
- ✓ The transfer rate is a variable that can be changed to study different scenarios, it depends on the administration policy in allowing mobility or not, we choose 5% for this simulation;
- ✓ The endogenous factor probability of occurrence;
- ✓ The exogenous factor probability of occurrence;
- ✓ Minimum age and maximum age ;
- ✓ The simulation time horizon ;

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HRM functions

Promotion

There are two possibilities to get promoted:

-First case: competition:

To participate in a competition for a grade promotion the candidate has to fulfill the following conditions:

- Antiquity in the grade (5 years in our example);
- A good annual scoring;

-Second case: promotion by antiquity only:

It means that an employee even if he failed in many competitions he can get promoted by antiquity in the condition that:

- Passing 10 years as antiquity;
- Having a good annual mark;
- An annual quota is admitted to this kind of promotion in the grade;

The inconvenient of this kind of promotion is that it comes very late

Recruitment

The annual number of employees to recruit equals to the annual needing people with consideration of the technological factor. The needing people number consists of all kinds of departures that occur in the year like; retirement, mobility, unsatisfied employees, early departure.

The HR manager has also to consider the future demand to confront with the HR supply forecasting in order to determine the gap between HR demand and supply.

Unsatisfied employees

In his career an employee can decide by his own to change his job because of endogenous or exogenous conditions, this situation makes the employee uncomfortable and so decides to think of an alternative outside, these conditions are as follow:

- Endogenous conditions: they concern the administrative situation, workload, professional relations quality… Reio and callhan [35] experienced that individual's emotions influence negatively the socialization learning process and, as a result, influence overall job satisfaction., the study have concerned 200 employees in service industries.

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- Exogenous conditions: they concern all the changes that come from the external environment and affect the professional life of an employee like: new government laws or the personal preferences while comparing his situation with salaries of the private sector.

Employee's preference function

It concerns the preference of an agent according to the probability of occurrence of an endogenous or exogenous event [36]. It also takes into account its annual score; antiquity and his perception of the professional relations quality within a service. Allen [37] suggested that socializations tactics influence the newcomers in building strong relationship with their colleagues and have a lower probability of worker turnover. In the same context Saks et al [38] have found that there is a relatively strong relationship between socialization tactics and the successful onboarding of new employee's. The authors attempt to speak to the limitations of socialization strategies and suggest other possible theories.

The framework chart process

It illustrates the life cycle of an employee and the reasons leading to a departure as it was stated before, the career of an employee begins from recruitment to departure; this last is caused mainly by retirement; mobility and the unsatisfied employees in their work because of internal or external factors. The following chart; (Fig 5) presents the main steps of the proposed ABM framework.

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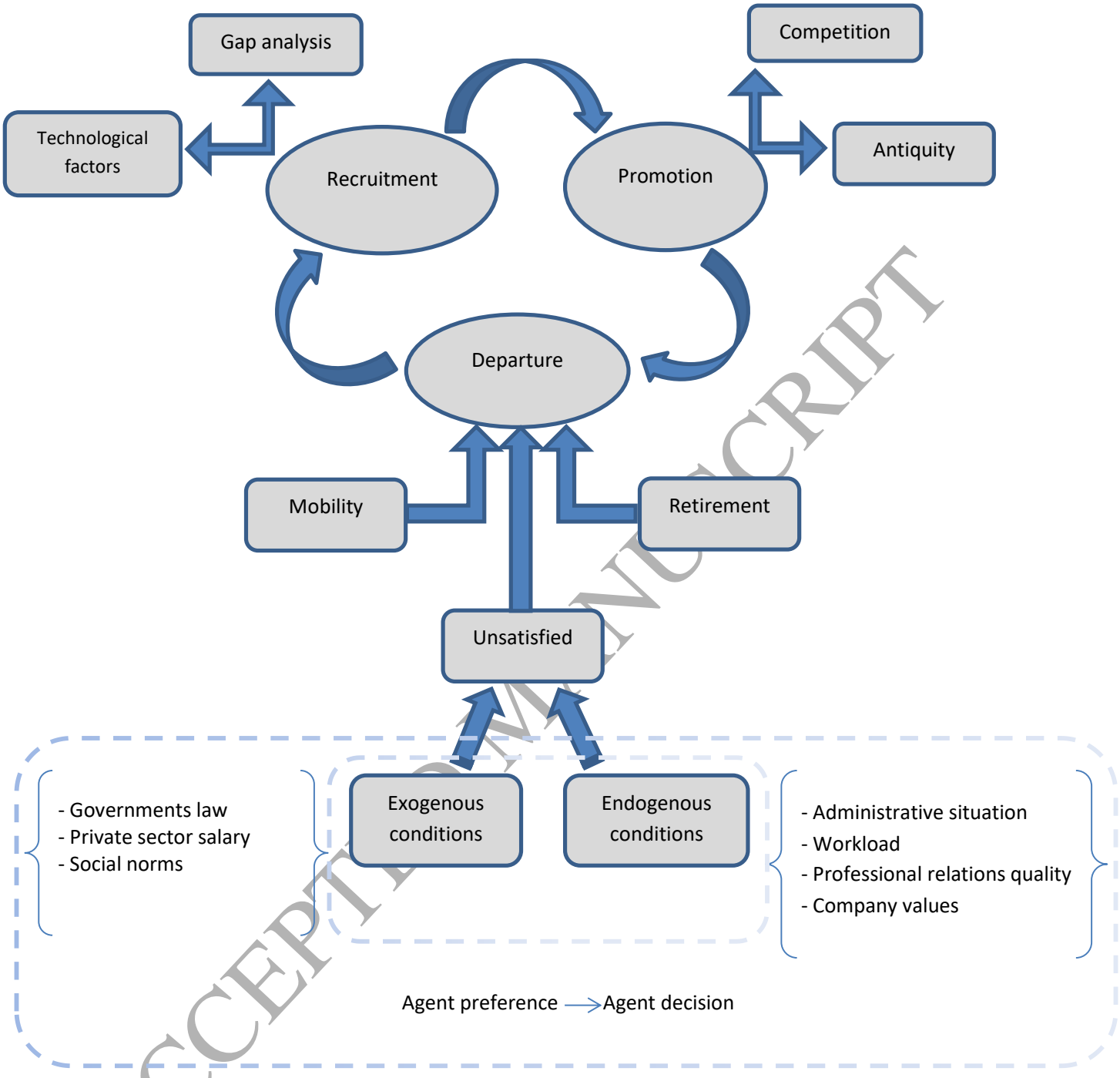

Figure 5. The framework process chart

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The different forms of interactions

The following graph illustrates the decision making mechanism and the different forms of interactions between agents each other and with the environment, (Fig 6).

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The chart can be read as follows:

- Exogenous factors coming from :
    1. External shocks: changes or new events which affect the agent decision, it is a kind of agent – environment interaction.
    2. Problems leading to a strike (for example salary raising claims), we have here a form of an agent – agent interaction because the success of the strike depends on its spread between employees, to do so each one tries to influence his neighbor to join the strikers.
- Endogenous factors include :
    1. Administrative condition, workload
    2. Personal satisfaction influenced by the agent preference, in this step the HR system is divided into four services (families of grades) so that every agent can evaluate his professional relation quality in his service, he compare it to the mean of employees altruism (professional relation quality) in that service; we have here a kind of an agent – agent interaction because the level of altruism in a service affect the employee in the way that if he is unsatisfied he can decide to demand a transfer or choose to quit.

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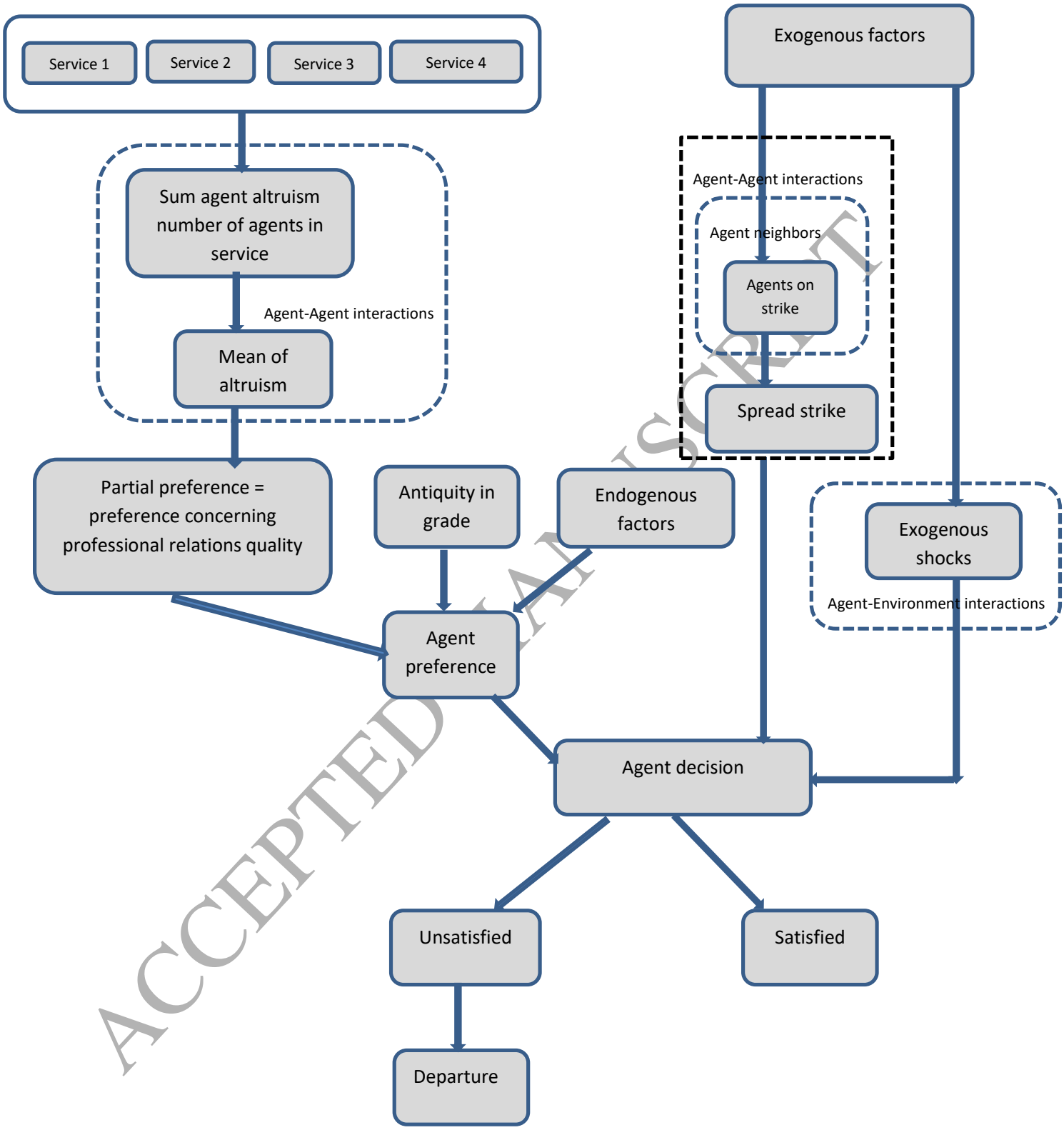

Figure 6. Forms of interactions graph

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The procedures of the program coding are illustrated in the following flow chart (Fig. 7). This flow chart illustrates the principal procedures and steps of the program coding from the variables initialization to the life cycle steps of an employee. The unsatisfaction procedure is detailed on the right.

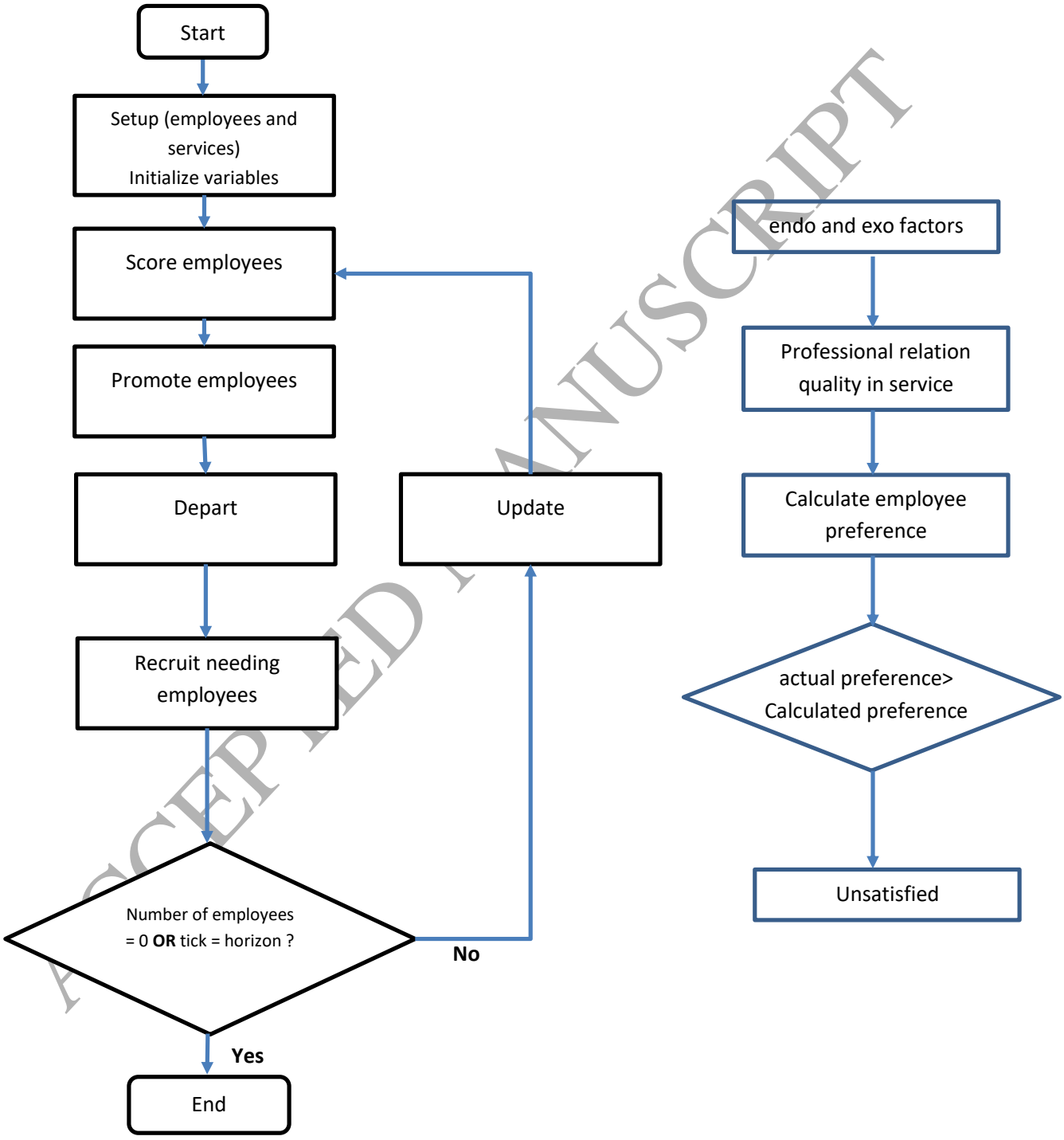

Figure 7. The first framework model flow chart

The Netlogo interface user

The following figure (Fig 8) represents the Netlogo interface user where the different variables described can be modified to experience the different scenarios.

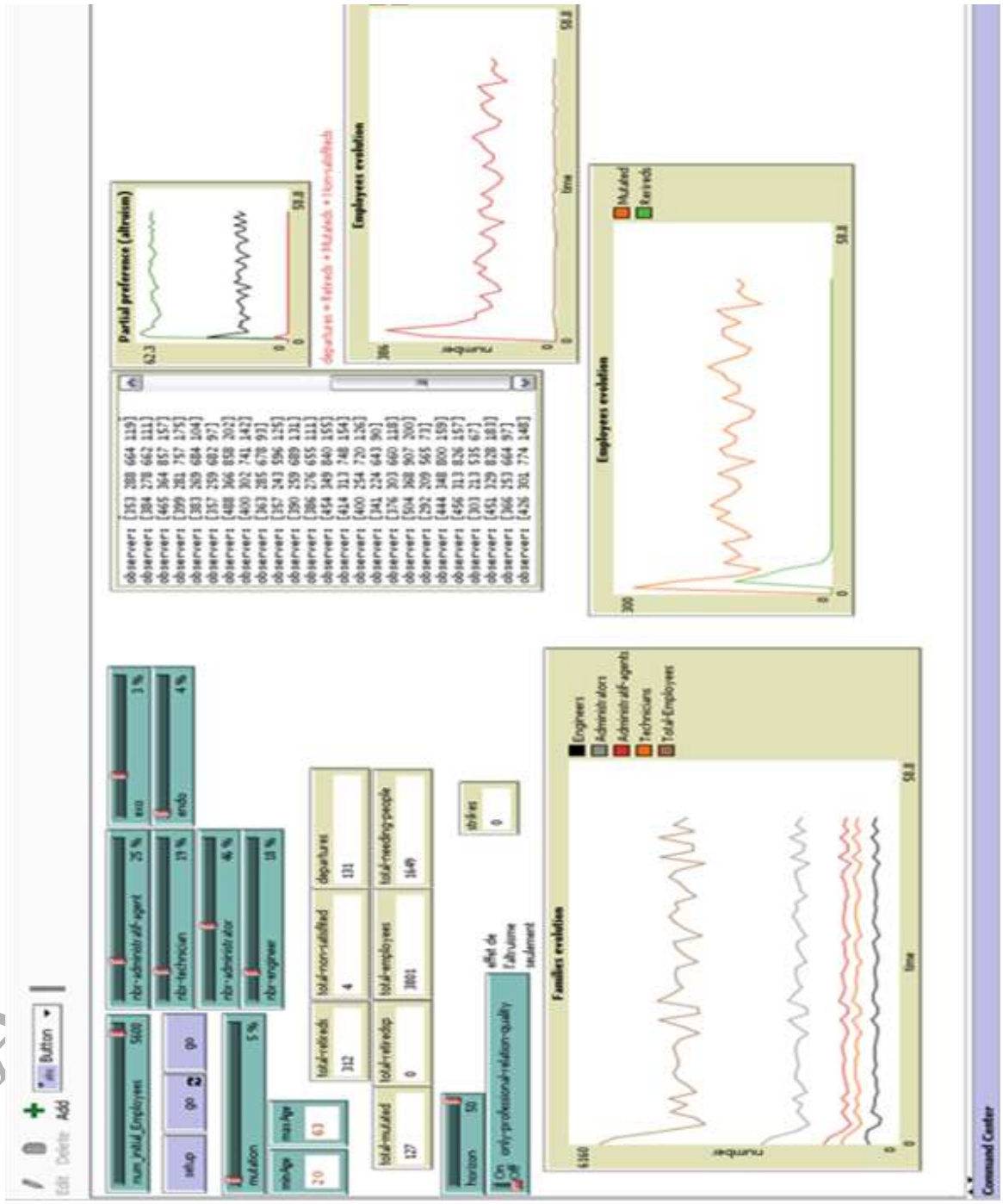

Fig 8. The Netlogo interface user

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The Netlogo coding

Employee attributes:

Turtles-own *:* they are all the characteristics of an agent and it's properties, they include :

- Grade;
- Age;
- Person-type ;family type;
- Level;
- Antiquity;
- Preference;
- Partial-preference ; (preference relative to professional-relation-quality);
- Score;
- Mutated;
- Professional-relation-quality;
- Mean-altruism-in-my-service;
- My-service-number ;
- On-strike;

Principal procedures:

They concern the events happening in an agent career, they represent all the actions taken by an employee after evaluating his internal and external environment, the figure 9 is a screen capture of the Netlogo interface user listing all the procedures of the program coding.

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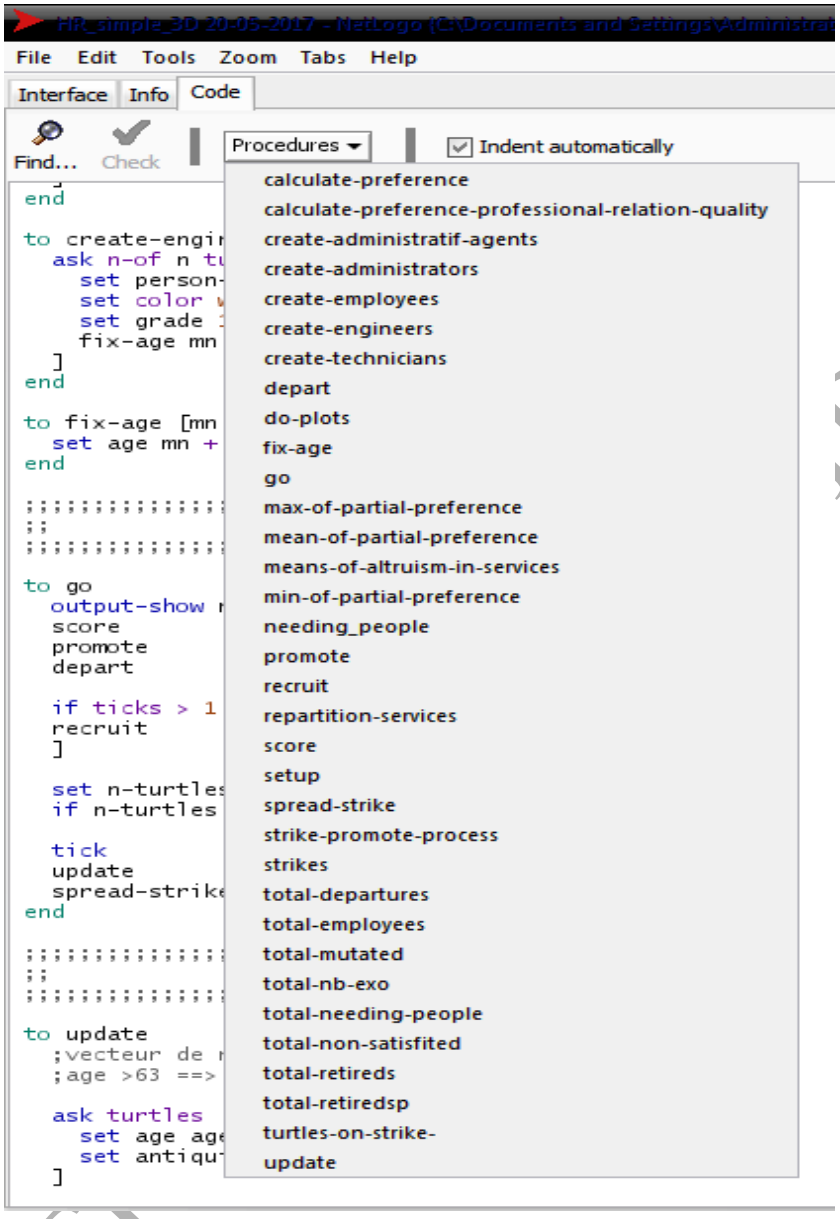

Figure 9. The principle procedures in Netlogo coding

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Results and discussion,

According to Epstein [39] to have reliable results we must have an average simulation number to run between 30 and 50, for this reason Netlogo allows to run these simulations through the behavior space feature (fig 10). The inputs to take into consideration for this operation are:

- Initial number of employees in each family;
- Mutation rate (5%);
- Three possible probabilities of occurrence of an exogenous event : 0%, 5%, 10%;
- Five possible probabilities of occurrence of an endogenous event : 0%, 10%, 30%; 50%, 70%;
- Horizon time (50 periods);
- Number of simulations (50 times);

The demanded outputs that will be calculated and summarized in the excel spread sheet concern mainly for each simulation:

- Departures;
- Total-nb-exo;
- Total-retireds;
- Total-non-satisfited;
- Total-mutated;
- Strikes number;
- Turtles-on-strike;
- Number of engineer;
- Number of administrator;
- Number of technician;
- Number of (employees) count turtles;

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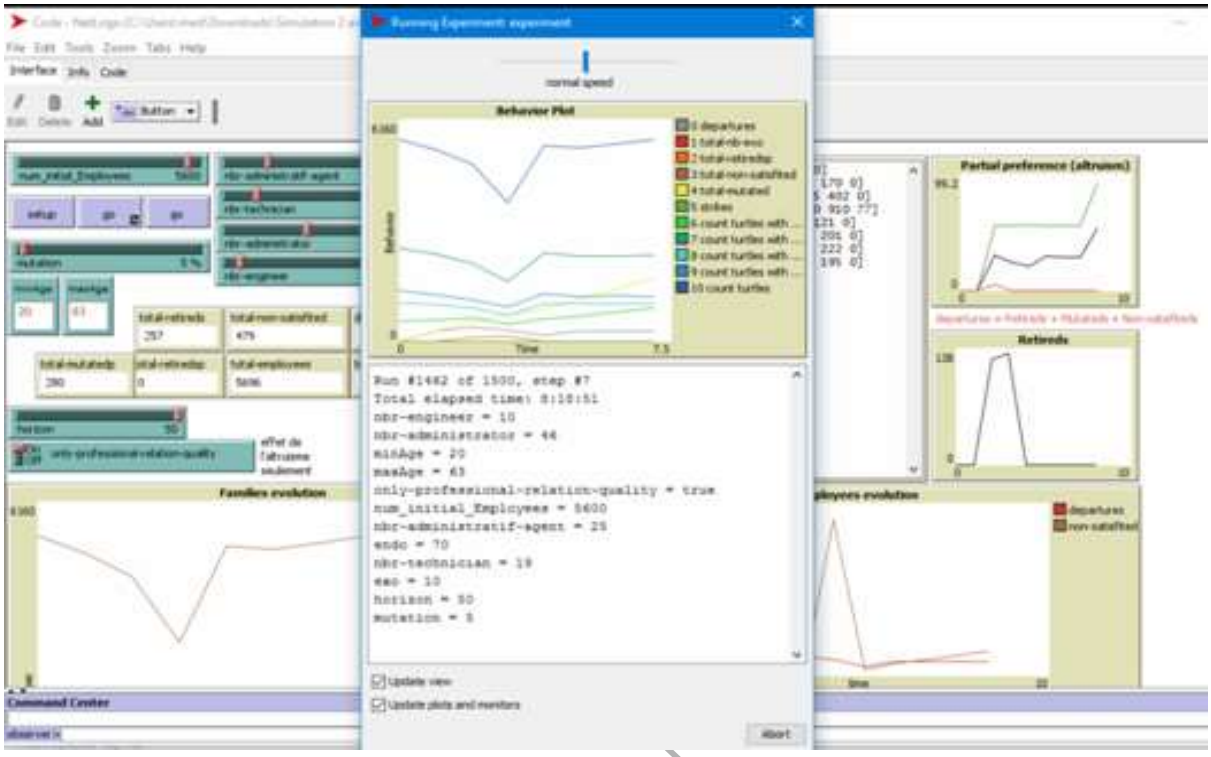

Fig 10. Behavior space interface

Figure 11 shows an example of an emergent phenomenon occurring for the scenario endo=70% and exo=10% where the departure exceeds 4000.

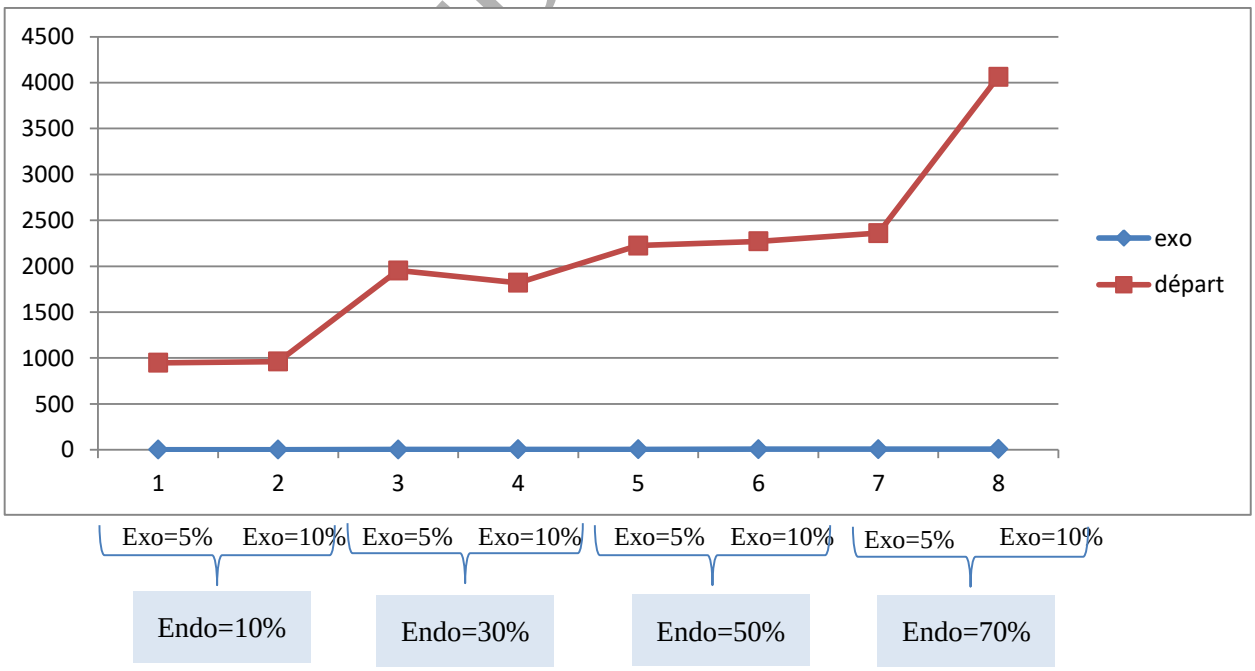

Figure 11. Variation of the departures according to the variables endo and exo

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The HR structure in this simulation is illustrated in the table 1:

	Engineer	Administrator	Technician	Administrative agent	Total HR structure
Initial structure	560	2576	1064	1400	5600
Average number Endo=70% , Exo=10%	432	1869	781	1010	4094

Table 1. HR structure for the scenario Endo=70% , Exo=10% (average)

The table 2 presents all results for the simulation of a time horizon of 50 periods conducted 50 times, the results are matrices of 2550 lines for each exo/endo scenario, in each scenario we calculate the mean of each output, the results concern the mean of the numbers of departures and the numbers of employees in each family.it appears that the number of departures increases every time the probability of occurrence of an endogenous or exogenous factors grows, the opposite happens for the total employees of each family.

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	initial	Annual mean					560	2576	1064	1400	5600
		departures	nb-exo event	retirees	non-satisfited	turtles-on-strike-	engineer	administrator	technician	administratif-agent	count turtles
	exo=0%	1170,26	0,00	8,09	1115,49	0,00	518,59	1961,67	827,46	1056,91	4364,63
	exo=5%	1173,51	0,97	7,60	1120,81	310,95	520,34	1959,18	826,97	1055,67	4362,16
	exo=10%	1196,85	2,40	5,92	1152,74	473,31	508,45	1946,11	821,17	1048,66	4324,40
endo=10%											
	initial						560	2576	1064	1400	5600
	exo=0%	1333,14	0,00	6,29	1323,65	0,00	436,50	1882,22	787,13	1017,41	4123,26
	exo=5%	1338,18	1,51	5,20	1331,13	244,07	435,19	1877,22	785,08	1015,24	4112,73
	exo=10%	1335,84	2,52	5,34	1327,57	480,68	435,25	1877,66	784,83	1015,48	4113,22
endo=30%											
	initial						560	2576	1064	1400	5600
	exo=0%	1349,07	0,00	5,16	1344,46	0,00	433,73	1874,37	783,25	1013,59	4104,94
	exo=5%	1349,32	1,46	4,86	1345,34	244,00	433,27	1873,10	782,83	1013,00	4102,20
	exo=10%	1350,32	2,58	4,36	1347,52	478,30	432,61	1870,25	781,87	1011,61	4096,35
endo=50%											
	initial						560	2576	1064	1400	5600
	exo=0%	1349,70	0,00	4,91	1346,00	0,00	433,75	1873,93	783,31	1013,10	4104,08
	exo=5%	1349,47	1,21	4,47	1346,33	243,75	433,29	1872,79	782,22	1012,58	4100,89
	exo=10%	1355,53	2,73	3,94	1354,22	480,91	431,82	1868,40	780,96	1010,59	4091,77
endo=70%											
	initial						560	2576	1064	1400	5600
	exo=0%	1351,35	0,00	4,58	1348,22	0,00	433,37	1873,01	782,88	1012,95	4102,21
	exo=5%	1352,83	1,23	4,48	1349,93	244,68	432,98	1872,05	782,36	1012,11	4099,50
	exo=10%	1354,34	2,68	4,08	1352,35	480,53	432,40	1869,50	781,48	1010,85	4094,22

Table 2. Results of the simulation (horizon time = 50 periods, number of simulations = 50)

Table 3 summarizes the emergent phenomenon number for all scenarios and also the expected annual average frequency of an emergent phenomenon. It appears that the number of emergent phenomenon increases every time the probability of occurrence of endogenous or exogenous factors grows.

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		Nb of emergent phenomenon		Annual average frequency of an emergent phenomenon	
endo=10%		Departures	total-employees	Departures	total-employees
	exo=5%	12	12	0,0047	0,0047
	exo=10%	11	11	0,0043	0,0043
endo=30%					
	exo=5%	9	8	0,0035	0,0031
	exo=10%	14	13	0,0055	0,0051
endo=50%					
	exo=5%	8	8	0,0031	0,0031
	exo=10%	14	14	0,0055	0,0055
endo=70%					
	exo=5%	11	9	0,0043	0,0035
	exo=10%	15	16	0,0059	0,0063

Table 3. The expected annual average emergent phenomenon frequency (50 simulations, 50 periods) for all scenarios

Example of a scenario interpretation: endo = 10%, exo = 5%,

Figure 12 presents the variations of departures after the simulations classification for the case endo = 10%, exo = 5%. It appears clearly that the massive departures are grouped in the upper right of the figure. There are 12 times where we have an emergent phenomenon corresponding to a massive departures (counted from the classified departure column of the excel sheet), if we divide this number by 2550 to get an annual average frequency; it will represent 0,0047.

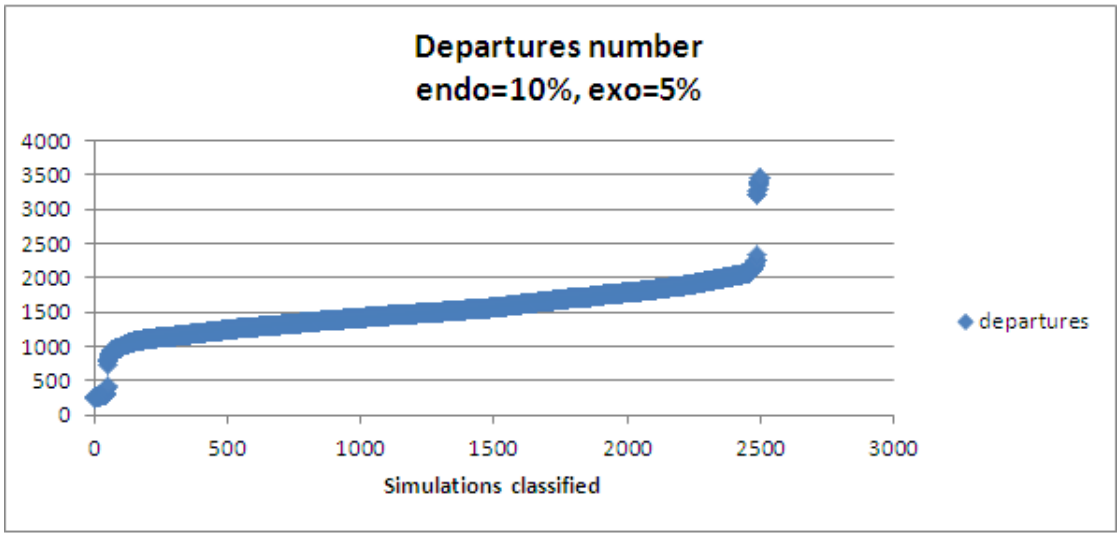

Figure 12. Graphical representation of the departures number classification. Scenario 1: endo = 10% and exo = 5%

Figure 13 presents the total employees number evolution after the simulations classification, we can see the opposite of the graph in figure 8, it means when the departure is big the total number of employees is small, we observe 12 times the emergent phenomenon that are grouped in the lower right of the figure (counted from the classified total employee column of the excel sheet), which represents also an annual average frequency of 0,0047.

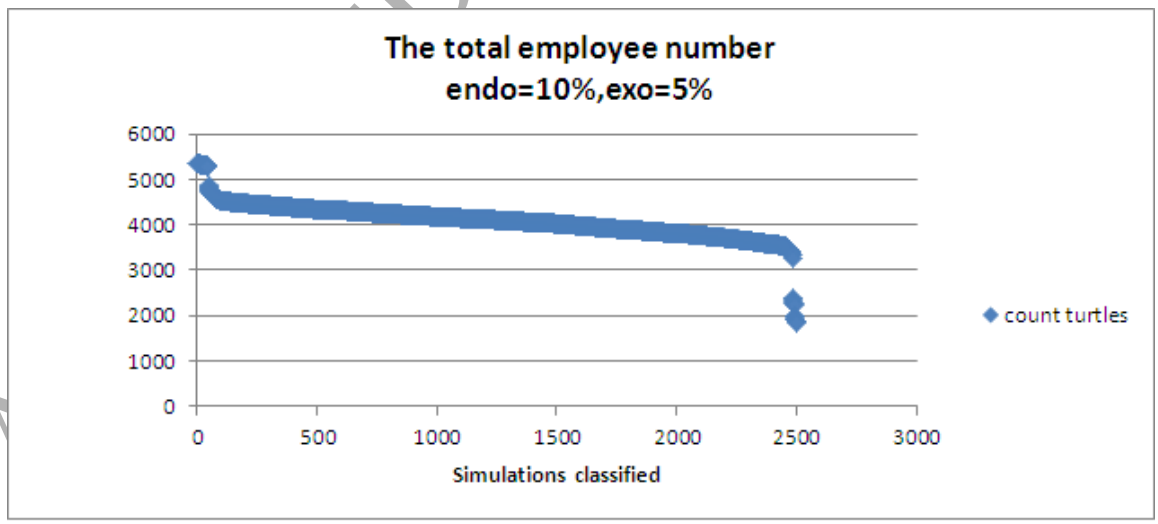

Figure 13. Graphical representation of the total employee's evolution classification. Scenario 1: endo = 10% and exo = 5%

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Conclusion

HRM has a major impact on individual and so on productivity and organizational performance. Effective strategic management requires effective HRM. SHRM implies the ways in which HRM is crucial to organizational effectiveness. Hence organizations have to carefully design strategies related to HRM in order to achieve a greater competitive performance.

The present paper presents an overview of the SHRM field by making light on the main concepts and steps of the strategy formulation, in the same time models and scientific tools have been used to enhance the HRM to a modern branch of science.

ABM is a method to study complex systems, in this paper the HR system represents a complex social system that is highly depending on human behavior. An ABM framework was proposed, it is experienced that internal and external conditions of the HR environment lead to emergent phenomenon that was reported as an identification of departures due to the employees decisions taken after the different interactions occurring between employees and with the external environment.

Organizations today are facing new facts that require radical changes in HR policies, in this context there are new challenges that have been identified, beginning by developing leaders and succession plans, giving attention to employee commitment and social climate, in this context the above modeling can give a view to the HR managers concerning the level of satisfaction among workers and so avoid employee turnover and the cost of replacing them.

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