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DEPARTMENT OF
ECONOMICS AND STATISTICS
WORKING PAPER SERIES

Quaderni del Dipartimento di Scienze
Economico-Sociali e Matematico-Statistiche

ISSN 2279-7114

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Working paper No. 8 - May 2012

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Abstract

We present a simplified model to provide a virtual laboratory to test the effects of the use of different performance evaluation measures to design manager's incentives in a project-based professional service organization. Our company's owner has to cope with the scheduling of multiple resource constraint projects in real time (RCMPSP), and with the design of the production manager incentive, whose variable wage is tied to some measures of the performance, which are proxies of the original owner's goal. We propose an agent based model approach where the agents' intelligence lies in the choice of the scheduling sequences. A discrete event simulator (DES) executes the projects, allocating in real time, the limited resources available. A Genetic Algorithm, evolving the sequence, randomly generated, uses the DES to simulate the effect and ranks the solutions. In this way, we investigate the incentive alignment problem as a resource allocation problem, comparing the results deriving from their respective "good solutions".

***JEL* classification:** C63, D23, L2, M12.

Keywords: Complex System Dynamics, Resource constrained multi project scheduling, Incentive Design, Performance Evaluation Measures, Genetic Algorithm.

1 Introduction

Very often a firm's owner has to implement an incentive schema to induce the manager to act as if he were one himself. She/he can hardly ever use her/his own goal's measure to evaluate the manager's performance. The models developed, in classic literature, for designing incentives and for checking their goodness are difficult and in most cases impossible to implement due either, to the simplified assumptions used, that cannot be applied to complex organizations like many types of firms, or to the lack of the necessary data. The aim of this paper is to present a model to evaluate the effects on the decisions taken by a manager, given a certain incentives schema set by the owner using an agent based model (ABM, henceforth) approach. We will investigate the issues that could arise from the incentive design, by using a virtual enterprise, which is a toy model of a real world project-based professional service organization, like engineering or software houses firms. These organizations have to decide which commercial opportunity to pursue and the priorities in the allocation of a fixed number of available resources on the projects. This type of problem is known as Resource Constrained Multi Project Scheduling Problem (henceforth, RCMPSP). The RCMPSP has been extensively studied to find a method to optimize production while reducing the project delay. However, in these companies, the RCMPSP can represent much more than a project management process, which "...is a complex decision-making process involving the unrelenting pressure of time and cost by itself" (Bayer & Gann, 2006). In fact, it could be seen as strategic for the short and long-term results of the company.

In this work we look at the non linearity feature of the involved production function in a very different perspective. The problem we will investigate is not the optimization of the firm's production output in itself, but the effect on the manager's decisions deriving from the incentive schema that the owner has to implement to induce the manager to act as if he were one himself. Hence, the focus is on the alignment between the owner's goal, and the performance measure used to incentive the manager. The ABM approach, as suggested by Terna (Terna, 2010), tries to avoid modeling a firm as a black box. Instead, with agent-based we can take into account the non linear consequences of the actions performed by agents to improve the organization: "frequently explainable only in terms of complexity" (Terna, 2010) .

The assumption is that the owner's and the manager's problem could have different solutions, due to the willingness of the first agent to maximize her/his own goal and the willingness of the second who wants to maximize her/his own wage. To solve the scheduling decision-making problem, we use a genetic algorithm search (GA, henceforth). Then we compare the schedules found with the owner's and the manager's fitness functions. By this way we will try to check how, the use of the different performance evaluation measures, for designing manager's incentives, influences the decision of the projects' schedule. The innovation of the chosen approach lies in the capability of the system of searching and implementing the "good solutions" to the owner's and manager's problems represented with their own fitness functions. Thanks to the ABM we will experiment every imaginable scenario, by executing the scheduling in a virtual lab (Ferraris & Morini, 2004). The main reference for the approach, chosen in this work, is the paper of Ferraris and Morini (Ferraris & Morini, 2004) , who use an ABM approach and a genetic algorithm to solve a "job shop" planning production problem. While the approach we have chosen is very similar, this paper differs from the previous one for the type of problem (RCMPSP), the focus over the study of the manager's incentives and finally, the software platform used for the model implementation. In this preliminary work, two different scenarios have been implemented and simulated as simple illustrative case studies to show the usefulness of the ABM approach to analyze the incentive alignment problem in a complex environment.

The rest of the paper is structured as follows: section 2 presents a brief review of the relevant theoretical economics literature on the incentive and the theoretical framework of this work. Section 3 presents the conceptual model. The architectural solution of the decision support system and of its components is illustrated in section 4. The results of the illustrative experiments are shown in section 5. The conclusions in section 6 summarize the main results of this preliminary model and put them in perspective.

2 Brief review of relevant literature and theoretical framework

The scholars of economics of organizations studied the theoretical issues that arise when we build measures to evaluate the managers' performances, (performance evaluation measures henceforth, PEM), using the signals of managers' effort, i.e. available accounting or statistical data described by Holmstrom and Milgrom (Holmstrom & Milgrom, 1991) . This issue is not only relevant to explain the theory of compensation ex-post. It is also extremely relevant to understand the effects of the incentive design on manager's behavior ex-ante, as underlined by later writers. Among them Baker (Baker, 2000) showed that the compensation of a multi-tasking agent not congruent with the owner's goal could result in a dysfunctional or "game the measure" behavior. He proposed the use of two parameters "distortion" and "noisiness" to measure this phenomenon.

2.1 **The issues of the classic theory**

The empirical verification of these measures has proved to be highly constrained by data limitation (Prendergast, 1999)[1]. Neither incentive design in real company can apply these models to check the "goodness" of the manager's incentive schema. The simplified assumptions used to build these models do not fit well enough to be applied in complex organizations like these types of firms[2]. As underlined from Gibbons, cited in Terna (Terna, 2010):

> *"For two hundred years, the basic economic model of a firm was a black box: labor and physical inputs went in one end; output came out the other, at minimum cost and maximum profit. Most economists paid little attention to the internal structure and functioning of firms or other organizations. During the 1980s, however, the black box began to be opened: economists (especially those in business schools) began to study incentives in organizations, often concluding that rational, self-interested organization members might well produce inefficient, informal, and institutionalized organizational behaviors."*[3]

2.2 **A new framework to study social science: the agent based model**

The advent of fast and cheap computing power has led to the development of a new tool[4] for doing economic research: the computational economics. The reason to adopt this new approach versus the traditional economic mainstream is clearly explained by Duffy (Duffy, 2005)**:**

> *"The orthodox neoclassical economic theory, approach that continues to characterize much of mainstream, is based on a deductive neoclassical*

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[1] *" ..at the very least the researcher needs data on some reliable measures of output and the contracts under which workers operate. Given the difficulty in getting reliable measures of performance on workers, it is not surprising that much of the literature on agency contracting has been concerned with estimating the existence of contracts compatible with the theory, rather than their effects. It is also surprising that most work on agency contracting has been done on wither sales force workers or CEOs, for whom contracts are most likely available" (Prendergast, 1999).*

[2] *I analyzed the issue in a previous work (Sorropago, 2010).*

[3] *Cited in (Terna, 2010).*

[4] *The epistemological classification of "Computational economics" as well as the definition of a "complex system" is far away from reaching a universal consensus among scholars. It is outside of the scope of this work to enter in this debate. Here we have used "tool" in the meaning suggested by J. Miller explaining why any theory could be developed using a "variety of tools" (Miller & Page, 2007) pag. 59.*

> *economic theorizing. This standard approach favors models where agents do not vary much in their type, beliefs or endowments, and where great effort is devoted to deriving closed-form, analytic solutions and associated comparative static exercises. By contrast, agent-based computational economic (ACE) researchers consider decentralized, dynamic environments with populations of evolving, heterogeneous, boundedly rational agents who interact with one another, typically locally. These models do not usually give rise to closed-form solutions and so results are obtained using simulations."*

The new tool has been applied to many fields of traditional economics from macro to microeconomics problems. The reader can refer to the Tesfatsion's website for a continuously updated reference bank of this kind of studies[5]: In the study of business and management system, the use of this approach to improve the design of manager's incentives in companies was reported by Bonabeau (Bonabeau, 2002) as a new company's practice in the 2002. In the last decade, the theoretical contribution to the study of the firm using this new approach has come particularly from computational organization theory. The organization viewed as a complex system, where heterogeneous agents interact, has been applied to study intra-firm dynamics as well as extra-firm dynamics (Terna et al., n.d.). The Computational Organization Theory as a new theory approach was formalized by Carley and Prietula (Carley & Prietula, 1994). Among the many contributions, to show the usefulness of virtual laboratory and a classification of the type of the models used for studying organization, we refer to Burton's clear analysis (Burton, 2003). Finally, J. Duffy has underlined the peculiar advantages of agent based model approach to study economic phenomena, while suggesting a complementarity of this approach with the human experimental economics (Duffy, 2005).

[5] HTTP://WWW2.ECON.IASTATE.EDU/TESFATSI/ACE.HTM.

2.3 The general framework and the technological platform to study organization

The major part of the debate on the validity of this tool results relates to the technical issues to build and validate these models based on computer technology. The reliability of the technological platform used to develop the models is relevant to the validity of the results.

Nowadays, several platforms have been designed and are available to implement such a type of models. Two of them are extremely relevant for our study: the Terna's (Terna, 2010) general framework based on Java technology and Uri Wilesky Netlogo platform developed at Northwestern University. The first has inspired the "conceptual model" of the simulator while we have used the second to implement the quasi-real production setting environment.

2.4 The RCMPSP, "job-shop" problem and agent based models

The RCMPSP deals with the issue of simultaneous management of multiple projects or of a portfolio of projects. The company has a certain number of projects, with a defined start date and a release or end date. Each project is composed of a series of tasks to be performed in a predefined sequence. Each task requires a certain number of different types of resources. The number of available resources is limited. Hence, when two or more different projects require, at a point in time, a number of the same resources in a quantity greater than available, allocating resources implies delaying the release date of one or more project. The RCMPSP has been extensively studied to find a method to optimize production while reducing the project delay. One of the most used methods to cope with such a type of problem is to define and optimize a performance measure to try to find an optimal schedule. This problem is defined NP-hard because there is "no known algorithm for finding optimal solutions in polynomial time" (Browning & Yassine, 2010). It has also been shown that it belongs to the class of "job-shop" problems[6]. Many researchers have proposed the use of computational methods to cope with this type of problem. Among others, we refer to Gonçalves, Mendes and Resende (Gonçalves et al., 2004) that suggest using the genetic algorithm.

3 The conceptual model

The model has been built using the "KISS" (keep it simple stupid) methodology, very common in the economics simulation model as underlined by Pyka and Werker (Pyka & Werker, 2009) it enables to use simple case-studies and modulate the subsequent enhancement.

3.1 The environment

Time is discrete. We consider a period T composed of a fixed number t of temporal units $t \in (1.......,T)$. The organization structure is very simple in this preliminary model. There is the production manager that has been delegated the responsibility of planning and scheduling the projects by the firm's owner.

To perform the projects the firm needs e employees with two different types of skill k where $k \in (1,2)$, that are in a fixed number, we denote them with e_{1n} and e_{2m} , where $n \in (1,2,...,N)$ and where $m \in (1,2,...,M)$. Each type of resource is endowed with a given cost rate per unit of time C_{e1}, C_{e2} .

3.2 The projects

Each deal is represented with a recipe. The "recipe"[7] is a full description of the project resource requirements. Figure 1 reproduces an example .

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[6] *Gonçalves et. al.refer to the work of Blazewicz et al. (1983) (Gonçalves et al., 2004) pag. 4.*

[7] *The use of "recipe" comes from Terna (Terna, 2010)*

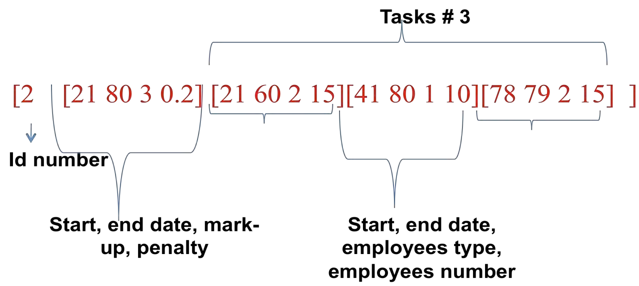

Figure 1: Example of "recipe"

There are I projects in the system. Each one denoted by *i*, where $i \in (1,2,\ldots,I)$, with a start date s_i and a delivery date d_i, , a markup μ_i and a unit time delay penalty cost δ_i . Each project *i* consists of *j* activities, where $j \in (1,2,\ldots,J)$. They have associated a task start date s_{ij}, a task end date d_{ij}, the type e_{ijk} of resources required and the quantity e_{ijn} or e_{ijm} required. Each resource can be assigned to just one activity. In this first simplified model the set of projects is exogenous. The decision over the projects to accept or to reject is taken once, at the project arrival date. The arrival date is identical to all the projects, t = 0. We assume that the activities of any projects should be performed sequentially in the order defined by *j*. Each task of the project can be started only if the required resources are available. Once the task has begun it cannot be interrupted. Each project could be accepted or rejected, if it is accepted it has the following cost:

$$c(i) = \sum_{j=1}^{J}(e_{ij1n}c_{e1} + e_{ij2m}c_{e2}) + (d_i^* - d_i)\delta_i. \qquad (3.2.1)$$

Where the first addend corresponds to the costs of the resources employed in the project, and the second one to the cost of the delay penalties given by the number of days of delay multiplied by the daily penalty cost of the project, and d_i^* is the effective end date..

The revenues are:

$$r(i) = \sum_{j=1}^{J} (e_{ij1n} c_{e1} + e_{ij2m} c_{e2})(1 + \mu_i). \qquad (3.2.2)$$

The production problem that should be solved is a RCMPSP, which in this context we define as the "schedule decision-making problem". According to the previous definitions, the decision is influenced by many interacting factors: project profitability, task sequence and resources required with respect to the resources availability. Browning and Yassine (Browning & Yassine, 2010) clearly defined the problem: " The RCMPSP entails finding a schedule for the activities (i.e., determining the start or finish time) that optimizes a performance measure such as minimizing the average delay in all the projects." In this work, we use a slight different definition because the measures relate with the owner's goal and the performance measure with the manager's wage. The schedule is a certain vector $\{x_i\}_{i \in I}$ that solves his/her problem. We will use respectively the following notation $\mathbf{x}^o$ and $\mathbf{x}^m$ for the solution to the owner's and the manager's problem optimization. For example, if we have I = {1,2}, the solution space is composed of x_1= {1}, x_2= {2}, x_3= {1,2}, x_4= {2,1}. In general we can compute the number of possible solutions, sequences without repetitions, *N* (v_i), *as* $\sum_{k=1}^{I} D_{I,k}$, *where* $D_{I,k} = \frac{I!}{(I-k)!}$.

As Arauzo and Pavon said "this solution integrates the strategic decisions of accepting or rejecting a project and the operative aspects of the resource allocation problem that is reflected in the priority given to each project in the schedule" (Arauzo & Pavon, 2009). Hence this sequence addresses both the strategic and the operational issues of the scheduling decision problem , that is what projects to accept or reject and which priority to give to the chosen deals, taking into account project values, profitability and the feedback of operational information.

3.3 **The incentive alignment as a scheduling decision problem**

The owner has his or her goal that is chosen among a certain set of relevant accounting figures she/he wants to maximize. We denote this generic function as $a_i(\mathbf{x})$, where $\mathbf{x}$ is the vector that represents the final schedule of the projects. The different manager's goal is to maximize his or her own wage. The manager's wage[8] is composed of a fixed and a variable component, the latter is set by the owner as a function of a performance measure chosen among the available accounting figures that could be a good signal of the manager's behavior. We denote with $w = f_i(p_i, \mathbf{x})$, a manager's variable wage function that depends on: the function f_i, the performance measure p_i used to evaluate his behavior, and the final schedule of the projects **x**.

4 The simulation architecture

Three main components constitute the ABM architecture: the recipes, the discrete event simulator (DES, henceforth) and the Genetic Algorithm engine. The genetic algorithm starts with a random generated schedule to find the “good solutions" assuming either the manager's or the owner's fitness function. Then it ranks the results and evolves the sequence. The DES, that replicates a quasi-real productive setting, takes in input the schedule, evolved by the GA, and in real time allocates the available resources. Finally, it computes the fitness measure and gives it back to the GA. The “recipes" is an external file that contains the projects specifications used for the case studies.

In this model we use "no minded" agents, like software objects in the Object-Oriented programming environment. (Ferraris and Morini, 2004). They encapsulate data and make

[8] This very common practice has been clearly explained by Holmstrom and Milgrom *(Holmstrom & Milgrom, 1991)* due to the fact that there are contracts in which there is more than one activity required by the agent, but the available signals to the principal are not in a relation of one to one, or they are not able to provide valid feedback on the effort the agent has allocated over the activity.

computations. The platform used to implement the DES is Netlogo (Wilensky, 2009-2011). In this environment the "no minded" agents perform actions in a certain time sequence "making thinks happening". We used the BehaviorSearch software tool (BS, henceforth) developed by Forrest Stonedahl and Uri Wilensky for implementing the genetic algorithm search. We refer the reader, to the site http://behaviorsearch.org, for the tool function description and documentation. This software allows setting up and performing the search running the model developed in Netlogo as a simulation engine. Figure 2 illustrates the sequence of steps and the software components. We refer the reader to chapter 5 and to Appendix C where we show some screenshots of the implemented model.

4.1 The discrete event simulator component - Netlogo

This is a toy model of a real world project-based professional service organization with its own employees, costs, basic business processes like the project scheduling or the firm and the project accounting. The agents are: projects, the manager and any other object needed to accomplish a particular task.

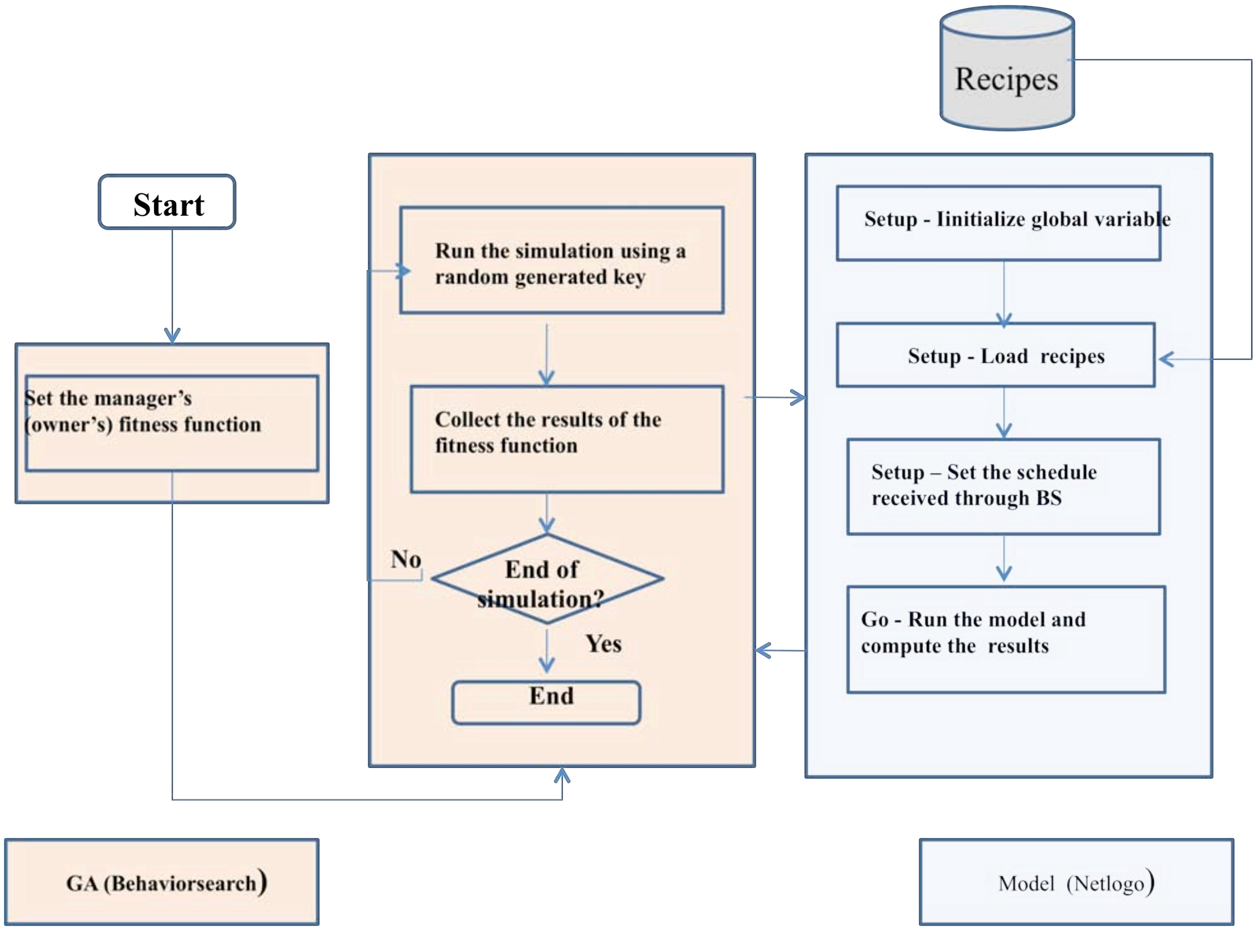

Figure 2 the Simulation architecture block diagram

To compare the owner's and the manager's goal we have used:

- A couple of measures derived from common practice suitable for representing the owner's goal:[9] the Gross Operative Production Margin (henceforth, GOP) that is a profitability measure, computed as the revenues less the costs (employees, delay, general expenses), and the average resource utilization (henceforth, ARU). The latter is a statistical indicator of the used productive capacity of the firm. It is a mean computed as

[9] This work is not a scientific analysis of the measures we are actually using, hence, we do not claim that they are the "best" or the "commonest", or that they are exhaustive representations of the real world practice. Only through a specific study can this objective be reached.

the ratio between the unit time worked on projects of each employee skill type per unit time and the total employee-working unit time available to the company.

- A manager's variable wage schema: there is a wide range of practices used to set and compute manager's wages. The pay-for-performance formula chosen for this toy-model is a relative measurement[10].

4.2 The GA component – BehaviorSearch

The owner's fitness functions is a specific function $a_i(\mathbf{x})$, in this case the GOP or the ARU, the manager's fitness function is a specific function $w = f_i(p_i, \mathbf{x})$, in this case the pay-for-performance formula[11] the owner would test as an incentive schema.

Given the enormous set of possible solutions, the GA searches the space with the well known paradigm introduced by J. Holland (Holland, 1975). The project's schedule is generated randomly in BS and then passed to the DES where each simulation runs with the new schedule and obtained the fitness measure, gives it back to the GA.

4.3 The "recipes" - data used for the case study

To implement the illustrative case studies we needed to set the parameters both of the virtual firm and of the "deals" or possible projects, which are the exogenous variables of the simulation.

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[10] The definition given of this schema in Atkinson et al . (Atkinson et al., 2001), is as follows "it includes rewards for meeting a target or provides a percentage of a bonus pool, or are based on performance in relation to an average."[10]

[11] The solution implemented in the simulation program allows the user to choose: one of the two owner's measures, GOP or ARU, the time horizon on which the variable wage is computed (T/2 or T), the performance target, that is a threshold over which the manager variable wage is due in a certain amount.

To simulate the economic structure of the real-world company, we set the firm's parameters (i.e. employee's numbers and costs) in the DES. The firm's parameters used for both the case studies are shown in table 1. The experiment time is equal to 480 unit time (T = 480). This period can be thought of as a two-year observation-time, each year, composed of 240 units, hence the first half, T/2 (240), could represent the end of the first year and T (480) the end of the second year. This is why we will use "yearly" to mean generally a parameter settled equally for one of the two halves. We will also use first half to refer to T/2.

Number of employee with skill 1 (N)	**Yearly employee skill 1 wage**	**Number of employee with skill 1 (M)**	**Yearly employee skill 2 wage**	**Yearly manager fixed wage**	**Max mark-up**	**Yearly general expenses**
20	70	15	100	500	3	300

Table 1 – Case study firm's parameters

The projects "recipes" are 25. Their details[12] have been reported in Table 2 in Appendix B. This data has been arbitrarily chosen using only reasonable criteria to run illustrative experiments. We have intentionally chosen a higher number of projects and tasks compared to traditional studies. In doing so, we have tried to show a more real complex environment and the capacity of a such simple system to work it out, even at the expense of an easy understanding of the results. In fact, the scope of this work is to show how this "tool" according to Miller's[13], could be used to afford such a type of economic problem.

[12] In the table we avoided to report the data used for the tasks of each project that could be easily read in the file recipes.

[13] (Miller & Page, 2007) pag. 59.

5 Simulation and results

The first case study is related to the use of a certain proxy of the owner's goal to measure the manager's performance. This is common in the real world, where we can hardly ever use the owner goal's measure to evaluate the manager's performance. In the second scenario, we investigate a subtler problem, the difference in the time horizon of the two agents. In this case, the question is "what if" we set the manager target to the "first half" while the owner has longer goal time horizon?" The preliminary results are illustrated in the following paragraphs.

5.1 First Case Study

Consider the firm's owner willing to maximize the GOP in period T while the variable incentive of the manager is computed using the Average Recourses Utilization. In this case, we assume that the owner has designed an incentive schema based on the manager's performance evaluated at the same time period, T. The experiment settings are shown in table 3.

	Fitness measure To maximize	**Time horizon**	**Manager incentive schema**	**Performance Measure used**	**Target**	**Variable wage formula**
Owner's	GOP	T	Fix wage + variable wage	ARU	50%	100 (ARU(T) / Target - 1)
Manager's	Variable Wage	T				

Table 3 – Experiment 1 Setting

In table 4 we show the owner's and the manager's schedules found. In table 5 the different projects chosen by the agents are highlighted.

Project order schedule position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Owner Schedule	15	6	18	11	20	19	22	12	1	4	16	17	23	14	10	2	9	
Manager's Schedule	18	3	23	12	6	8	15	19	1	2	16	9	4	11	17	13		

Table 4 – Experiment 1 – Results Schedule Comparison

Owner Schedule	1	2		4	6		9	10	11	12		14	15	16	17	18	19	20	22	23
Manager's Schedule	1	2	3	4	6	8	9		11	12	13		15	16	17	18	19			23

Table 5 – Experiment 1 – Result - Project accepted Comparison

Finally table 6 compares the relevant outcomes obtained with the scheduling vector resulting from the GA search.

	Owner's schedule	**Manager's schedule**
Revenues	8,471	8,315
Manager's wage	-1,068	-1,079
Employees' cost	-5,800	-5,800
Delays cost	-186	-176
General Expenses	-600	-600
GOP	**817**	**660**
ARU %	**84**	**89.6**

Table 6 – Experiment 1 – Owner's and Manager's Results Comparison

There is a remarkable difference between the agents' results that should be economically evaluated. It is quite clear that they seem to resemble to different strategic and operational approach. An intuition of the possible difference is that if the manager's goal is linked to the used productive capacity, he takes less care of the project profitability. To verify this intuition we show the detailed analysis of the two project-portfolios performance in table 7. The average mark-up of the owner's schedule is greater than that of the manager, like the cost due to the delays. The manager's scheduling decision allows a greater utilization of productive capacity at the expense of the profitability. Overall, the global result is that the use of the ARU, to incentive the manager, as a proxy of the GOP, seems to make the manager follow a different strategic and operational approach with respect to the one wished from the firm's owner. Figure 3 and 4 show the screenshots of the Netlogo model interface for experiment 1.

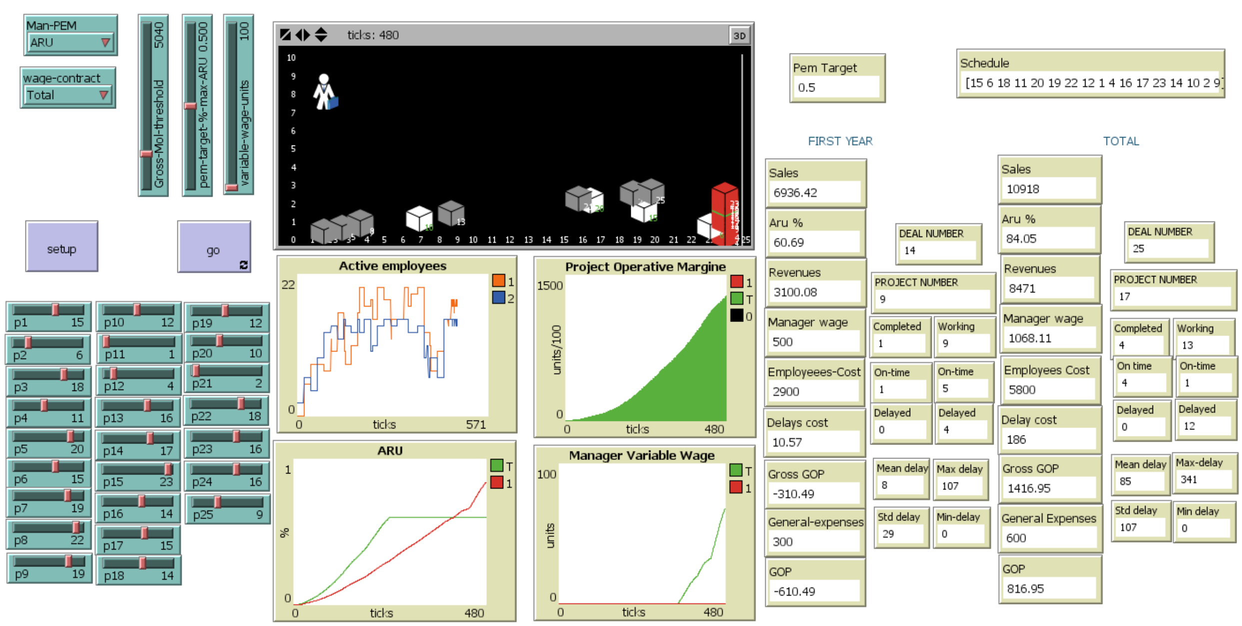


Figure 3 – Experiment 1 – Netlogo Interface - Owner's schedule simulation

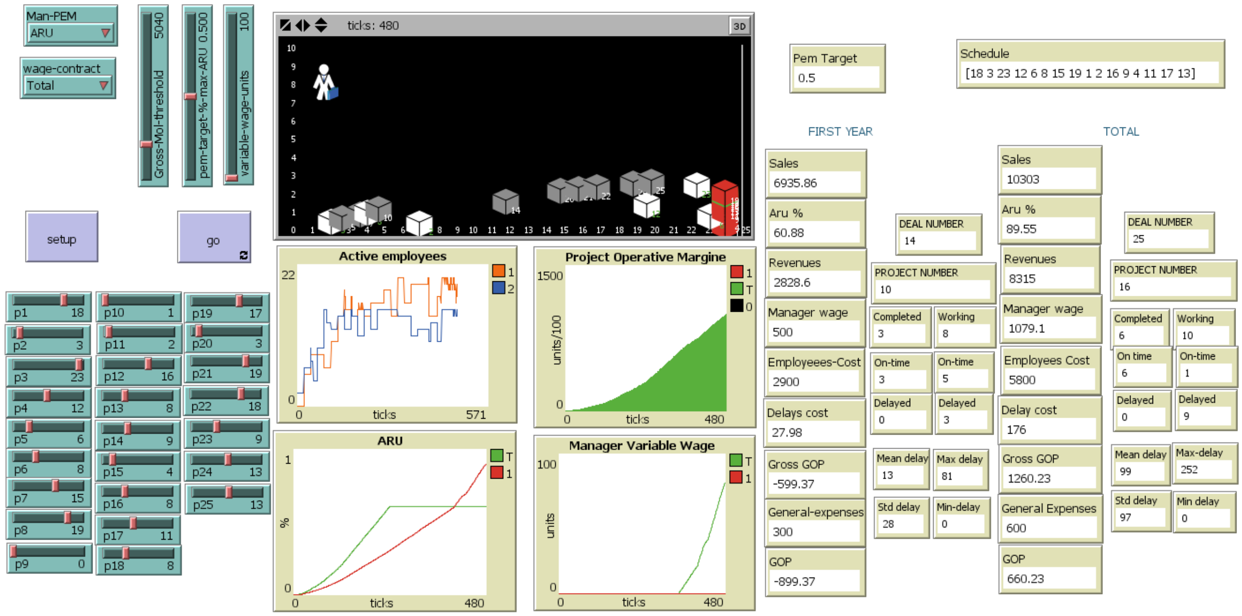


Figure 4 – Experiment 1 – Netlogo Interface - Manager's schedule simulation

Experiment 1 Owner's Result								
id	start	end	worked e1	worked e2	Total worked	revenues	employees costs	delay costs
15	241	391	391	433	824	471	294	0.0
6	80	464	1252	1036	2288	1434	797	0.0
18	280	632	860	523	1383	984	469	0.0
11	140	398	650	715	1365	1170	488	12.5
20	300	332	36	108	144	100	56	0.0
19	280	420	245	314	559	324	202	23.9
22	340	520	80	100	180	91	65	5.7
12	160	394	519	660	1179	725	426	9.9
1	1	367	1140	897	2037	1059	706	25.5
4	60	281	660	606	1266	890	445	38.4
16	260	387	356	240	596	163	204	11.4
17	260	349	100	160	260	58	96	8.5
23	360	449	100	166	266	157	98	7.2
14	240	265	75	147	222	133	83	11.7
10	100	144	88	119	207	143	75	0.0
2	20	144	348	326	674	309	237	17.0
9	80	432	348	323	671	260	236	14.8
Total			**7,248**	**6,873**	**14,121**	**8,471**	**4,978**	**186**
Average mark-up						**1.70**		

Experiment 1 Manager's Result								
id	start	end	worked e1	worked e2	Total worked	revenues	employees costs	delay costs
18	280	632	860	523	1383	984	469	0.0
3	40	47	0	24	24	10	10	0.0
23	360	449	187	267	454	265	166	0.0
12	160	394	642	705	1347	818	481	0.0
6	80	464	1252	1036	2288	1434	797	0.0
8	80	87	0	16	16	17	7	0.0
15	241	391	388	430	818	468	301	8.3
19	280	420	299	314	613	349	242	23.9
1	1	367	1264	981	2245	1166	799	21.2
2	20	144	348	327	675	309	238	0.0
16	260	387	566	240	806	212	276	11.4
9	80	432	973	770	1743	665	611	6.5
4	60	281	589	534	1123	789	435	40.7
11	140	398	329	351	680	581	274	31.7
17	260	349	160	184	344	74	131	8.1
13	180	276	234	251	485	173	197	24.3
		Total	**8,091**	**6,953**	**15,044**	**8,315**	**5,433**	**176**
Average mark-up						**1.53**		

Table 7 – Experiment 1 – Owner's and Manager's Results Detailed Analysis Comparison

5.2 **Second Case Study**

Consider that the owner wants to maximize the used productive capacity, ARU, over the period T, but the manager's incentive is determined on the outcome obtained at the end of the first half. In this case, the mis-matching measure is not between the measures used, but between the time horizon of the owner's and manager's goals.

	Fitness measure To maximize	Time horizon	Manager incentive schema	Performance Measure used	Target	Variable wage formula
Owner's	ARU	T	Fix wage + variable wage	ARU	50%	100 (ARU(T/2) / Target - 1)
Manager's	Variable Wage	T/2				

Table 8 – Experiment 2 Settings

In table 9 we show the owner's and the manager's schedules resulting found. In table 10 the different projects chosen by the agent's are highlighted.

Project order schedule position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Owner Schedule	16	6	20	18	15	14	3	7	11	13	1	12	8	4	2	5	10	9	25
Manager's Schedule	25	8	14	17	18	1	11	9	13	6	23	16	4	2	10	5	24	3	21

Table 9 – Experiment 2 – Result Schedule Comparisons

Owner's Schedule	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**		**18**	**20**				**25**
Manager's Schedule	**1**	**2**	**3**	**4**	**5**	**6**		**8**	**9**	**10**	**11**		**13**	**14**		**16**	**17**	**18**		**21**	**23**	**24**	**25**

Table 10 – Experiment 2 – Result - Project accepted Comparison

Finally table 11 compares the relevant results obtained with the scheduling vector resulting from the GA search at time T/2 and at time T.

	T/2 Results		**T Results**	
	Owner's schedule	**Manager's schedule**	**Owner's schedule**	**Manager's schedule**
Revenues	2970	3087	8536	6844
Manager's wage	- 521	- 534	- 1092	- 1,080
Employees' cost	- 2900	- 2900	- 5,800	- 5,800
Delay costs	- 35	- 28	- 195	- 199
General Expenses	- 300	- 600	- 600	- 600
GOP	**-786**	**-676**	**668**	**-835**
ARU %	**60.4**	**67.2**	**85.5**	**72.8**

Table 11 – Experiment 2 – Owner’s and Manager’s Results Comparison

In this experiment, we see, from the comparison of the agents’ solutions, an interesting case study where the manager’s successful attempt of maximizing her/his own performance in the short run could have disruptive effect in the long term on the firm's ARU, whereas the owner’s longer time horizon could result in a higher average used productive capacity at time T. In figure 7, we compare the resulting schedules plotting the total number of employees, for each skill type, working in each time unit. From this picture, we can see the negative impact of the manager’s decision over the resources’ allocation in the second-year. The result seems to confirm the well-known problem in the incentive design of the different agents’ time horizon in order to avoid opportunistic manager’s strategic and operational approaches. Figure 5 and 6 show the screenshots of the Netlogo model interface for experiment 2.

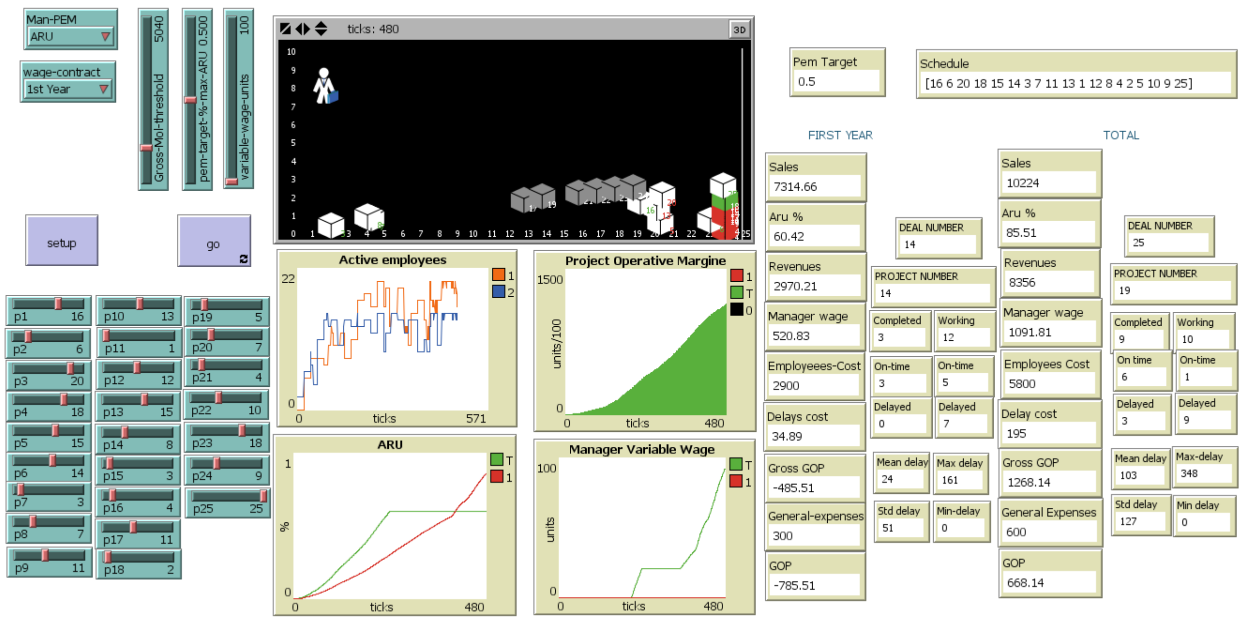


Figure 5 – Experiment 2 – Netlogo Interface - Owner’s schedule simulation

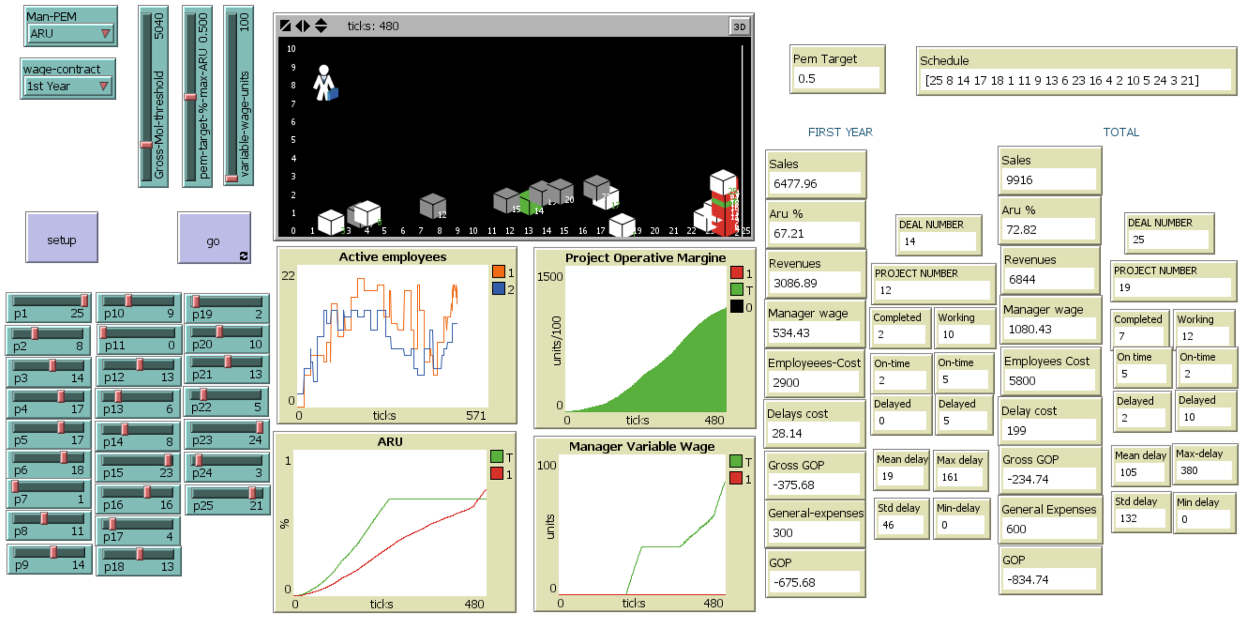


Figure 6 – Experiment 2 – Netlogo Interface - Manager's schedule simulation

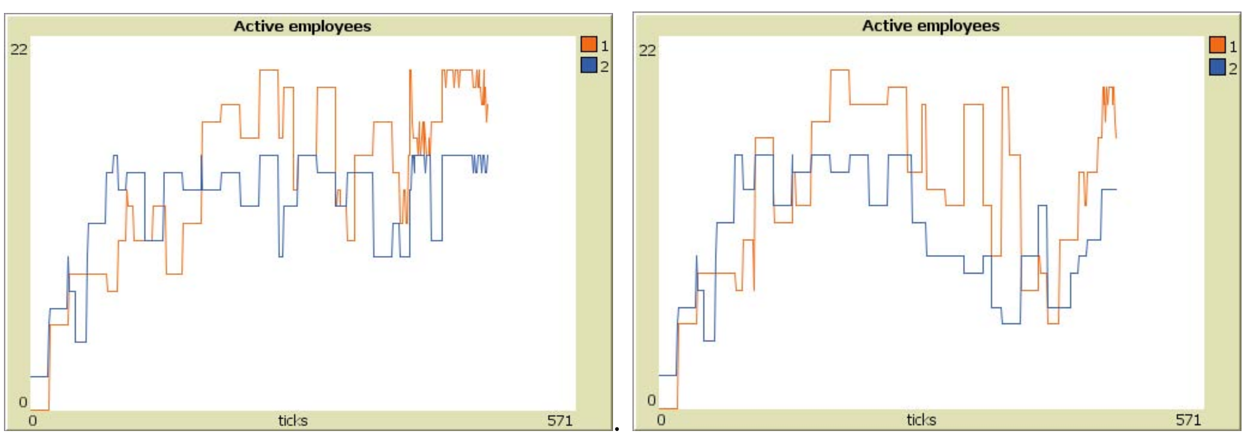


Figure 7 – Experiment 2

6 Conclusions and further developments

The economic literature has widely analyzed the issues of manager's incentives. The problem has mainly been studied by the contract theory, and has been explained by the effort misallocation . Nevertheless, the empirical verification of this theory has found limitation in data availability and it is well known that, "problems can turn up…for reasons of bounded rationality"[14], like the firm's owner of this company that has to cope with the RCMPSP. A new economic approach suggests of modeling such a type of problem by a multi-agent system. According to these ideas we have developed a small prototype, with the scope to verify the usefulness of these techniques for our incentive design problem. We have approached the problem using the KISS methodology. To keep the project simple, in this preliminary work, we assumed the cost of effort equal for both the actors and for all the projects . The ABM is composed of a genetic algorithm with a discrete event simulator, where the agents' intelligence lies in the search of "good solution" while the agents of the DES, projects and resources, are no-minded . We made a couple of experiments on a dataset of projects arbitrarily chosen (case-study) and hypothesizing real "what if" problems. Then, using the genetic algorithm engine, setting the different fitness functions for each of the agents, we found their respectively "good solution". The sequence found by the system, addresses the issues both, strategic and operational of the scheduling decision problem, that is accepting or rejecting a project and which priority to give to the chosen deals taking into account the project values, the profitability and the feedback information. The results obtained with the found sequence have been compared. Hence, we have analyzed the differences in the economic figures emerging in the experiments as mis-resources allocation. We run two simple experiments using different measures or different time horizon , between the owner's goal, and the manager incentive. The preliminary outcomes of these illustrative experiments, seem to show the usefulness of such a tool in an environment characterized by agents that are rationally bounded, due to the enormous calculation required

[14] (Macho-Stadler & Perez-Castrillo, 2001) footnote 3 pag. 19.

to find a good solution. The analysis of the results seems to explain reasonably the differences found in the simple experiments, but there are still many issues to investigate. Future work will be devoted to introduce the cost of effort function and to test the proposed approach on more case studies.

7 References

Arauzo, A.J. & Pavon, J., 2009. Agent-based modeling and simulation of multiproject scheduling. *Inteligencia Artificial*, (42), pp.12 -20.

Atkinson, A.A., Banker, R.D., Kaplan, R.S. & Young, S.M., 2001. *Management Accounting*. 3rd ed. Upple Saddle River - NJ: Prentice Hall.

Baker, G., 2000. The Use of Performance Measures in Incentive Contracting. *The American Economic Review*, 90(2), pp.415-20.

Bayer, S. & Gann, D., 2006. Balancing work: bidding strategie and workload dynamics in project-based professional service organization. *System Dynamics Review*, 22(3), pp.185-211.

Bonabeau, E., 2002. Predicting the unpredictable. *Harvard Business Review*, March.

Browning, T.R. & Yassine, A.A., 2010. Resource-constrained multi-project scheduling: Priority rule. *Production Economics*, pp.212-28.

Burton, R.M., 2003. Computational Laboratories for Organization Science: Questions, Validity and Docking. *Computational and Mathematical Organization Theory*, (9), pp.91-108.

Carley, K.M., 1999. On Generating Hypoheses using computer simulations. *Systems Engeneering*, 2(2), pp.69-77.

Carley, K.M. & Prietula, M.J., 1994. *Computational Organization Theory*. Hillsdale, New Jersey: Lawrence Erlbaum Associates,Publishers.

Chang, M.-H. & Harrington, J.E.J., 2005. Agent-based models of organizations. In Judd, K.L. & Tesfatsion, L. *Agent-based computational economics*.

Duffy, J., 2005. Agent-Based Models and Human Subject Experiments. In Judd, K.L. & Tesfatsion, L. *Handbook fo computational economics*.

Ferraris, G. & Morini, M., 2004. Simulation in the textile industry: Production planning optimization. *SSRN eLibrary*. available at http://ssrn.com/paper=635363.

Gilbert, N. & Troitzsch, K.G., 2008. *Simulation for the Social Scientist*. Oxford University Press.

Gonçalves, J.F., de Magalhaes Mendes, J.J. & Resende, M.G.C., 2004. TD-668LM4 *A Genetic Algorithm for the resource constrained multi-project scheduling problems*. AT&T.

Holland, J.H., 1975. *Adaptation in natural and artificial system*. Cambridge (MA): MIT Prss.

Holmstrom, B., 1982. Moral hazard in team. *The Bell Journal of Economy*, 13(2), pp.324-40.

Holmstrom, B. & Milgrom, P., 1991. Multitask Principal-Agent Analyses: Incentive Contracts, Asset Ownership, and Job Design. *Journal of Law, Economics, & Organization*.

Kerr, S., 1975. On the Folly of Rewarding A, While Hoping for B". *Academy of Management Journal*, pp.769-83.

Macho-Stadler, I. & Perez-Castrillo, D.J., 2001. *An introduction to the economics of information*. Oxford University Press.

Miller, J.H. & Page, S.E., 2007. *Complex Adaptive Systems*. Princeton - New Jersey (USA): Princeton University Press.

Prendergast, C., 1999. The provision of incentives in firms. *Journal of Economic Literature*, XXXVII(March), pp.7-63.

Pyka, A. & Werker, C., 2009. The methodology of simulation models: Chances and risks. *Journal of artificial societies and social simulation*.

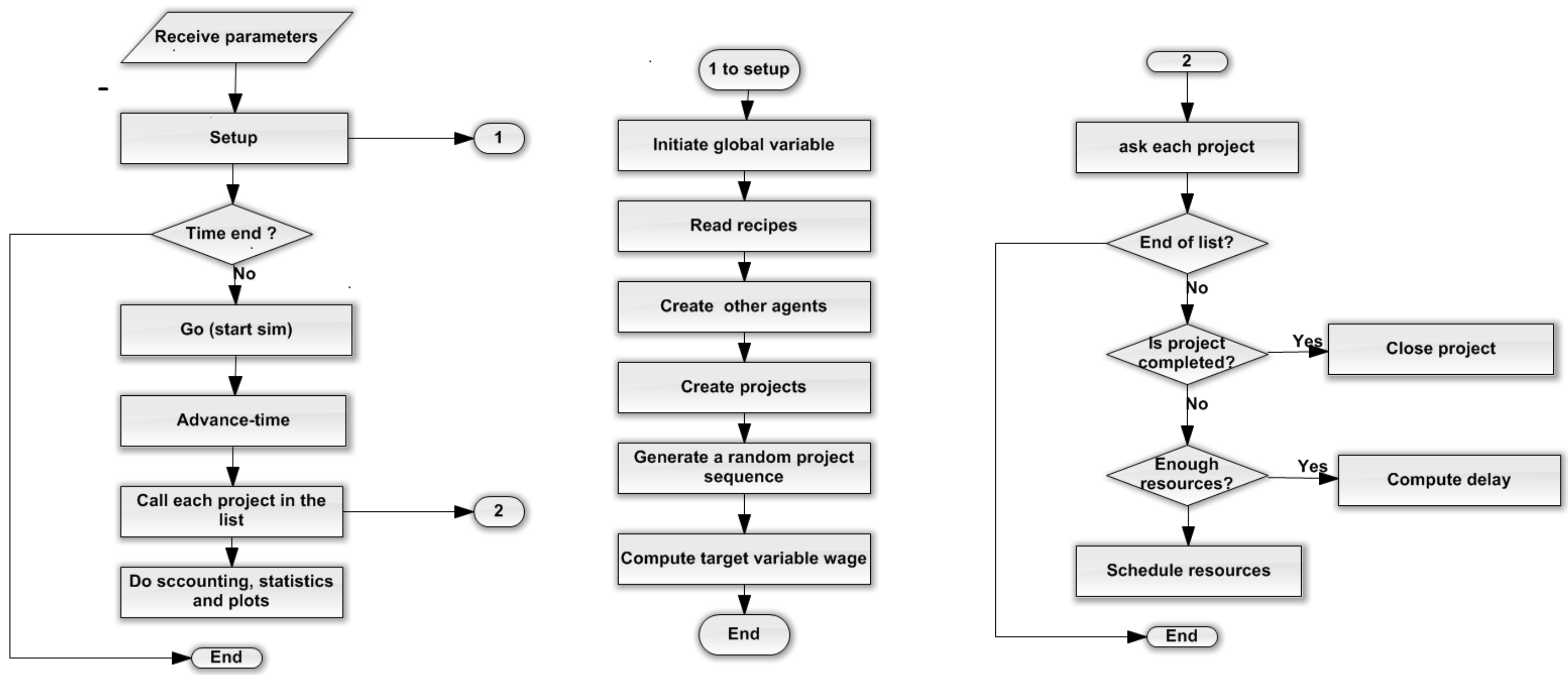
Sorropago, C., 2010. *How evaluation rules affect management:computing congruence of performance evaluation measures - a simulaion approach*. PhD Thesis. WP09 Contributions from DipECO, Dep. of Economics and Public finance.

Terna, P., 2010. An Agent-Based Methodological Framework to Simulate Organizations or The Quest for the Enterprise: jES and jESOF, Java Enterprise Simulator and Java Enterprise Simulator Open Foundation. pp.247-79.

Terna, P., Boero, R., Morini, M. & Sonnessa, M., n.d. *Modelli per la complessità - La simulazione ad Agenti in Economia*.

Wilensky, U., 2009-2011. *http://ccl.northwestern.edu/*. [Online].

8 Appendix A: Simulation Flow Diagram



9 – Appendix B: Projects used in the case study: details

id	start-date	end-date	Penalty (% of Sales)	mark-up	required-em1-days	required-em2-days	required total	delay-daily-cost	project-days-sales-b	project-sales-b	project-employee-costs-b	project-operative-margin-total-b
1	1	367	5	1.5	1268	981	2249	0.1595	2249	1167.88	778.58	389.29
2	20	144	2	1.3	348	327	675	0.0499	675	309.08	237.75	71.33
3	40	47	3	1	0	24	24	0.0429	24	10.00	10.00	0.00
4	60	281	4	2	663	606	1269	0.1614	1269	891.75	445.88	445.88
5	60	91	1	1.8	33	86	119	0.0264	119	81.83	45.46	36.37
6	80	464	3	1.8	1252	1036	2288	0.1121	2288	1434.30	796.83	637.47
7	80	91	2	1.9	0	24	24	0.0345	24	19.00	10.00	9.00
8	80	87	2	2.6	0	16	16	0.0495	16	17.33	6.67	10.67
9	80	432	2	1.1	1296	983	2279	0.0492	2279	866.34	787.58	78.76
10	100	144	2	1.9	88	119	207	0.0650	207	142.98	75.25	67.73
11	140	398	3	2.4	652	715	1367	0.1362	1367	1171.40	488.08	683.32
12	160	394	2	1.7	642	705	1347	0.0699	1347	817.70	481.00	336.70
13	180	276	4	1	356	351	707	0.1042	707	250.08	250.08	0.00
14	240	265	1	1.6	75	150	225	0.0540	225	135.00	84.38	50.63
15	241	391	2	1.6	391	433	824	0.0628	824	471.13	294.46	176.68
16	260	387	2	0.8	661	714	1375	0.0618	1375	392.23	490.29	-98.06
17	260	349	5	0.6	187	247	434	0.0531	434	94.48	157.46	-62.98
18	280	632	2	2.1	1456	839	2295	0.0924	2295	1625.93	774.25	851.68
19	280	420	5	1.6	420	483	903	0.1850	903	518.00	323.75	194.25
20	300	332	2	1.8	36	108	144	0.0624	144	99.90	55.50	44.40
21	320	443	1	1.5	332	22	354	0.0129	354	159.00	106.00	53.00
22	340	520	2	1.4	660	420	1080	0.0572	1080	514.50	367.50	147.00
23	360	449	4	1.6	187	267	454	0.1192	454	265.27	165.79	99.48
24	380	611	3	1.7	564	425	989	0.0754	989	580.69	341.58	239.11
25	400	478	2	1.9	214	255	469	0.0822	469	320.47	168.67	104.80

Table 2 - Case study recipes

9 Appendix C

The Netlogo program, the BS file searches and the data file are available on request.

The experiments could be repeated using the available BS files and setting the random seed of the GA to 1. The following pictures shows the screenshots of BehaviorSearch for setting the GA search and the results obtained for the illustrative case 1.

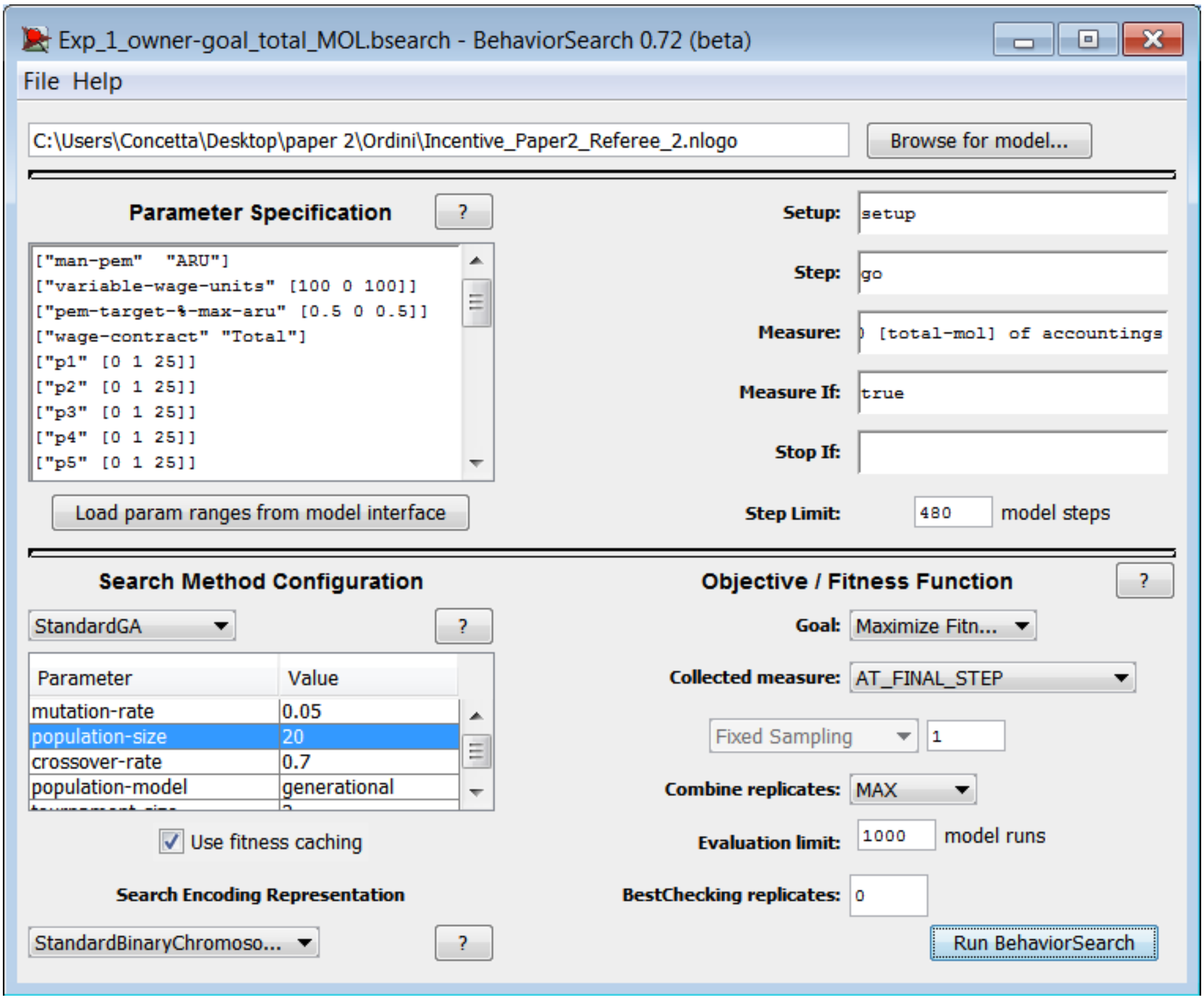


Figure 8 – Experiment 1 – BehaviorSearch – Owner Search Settings

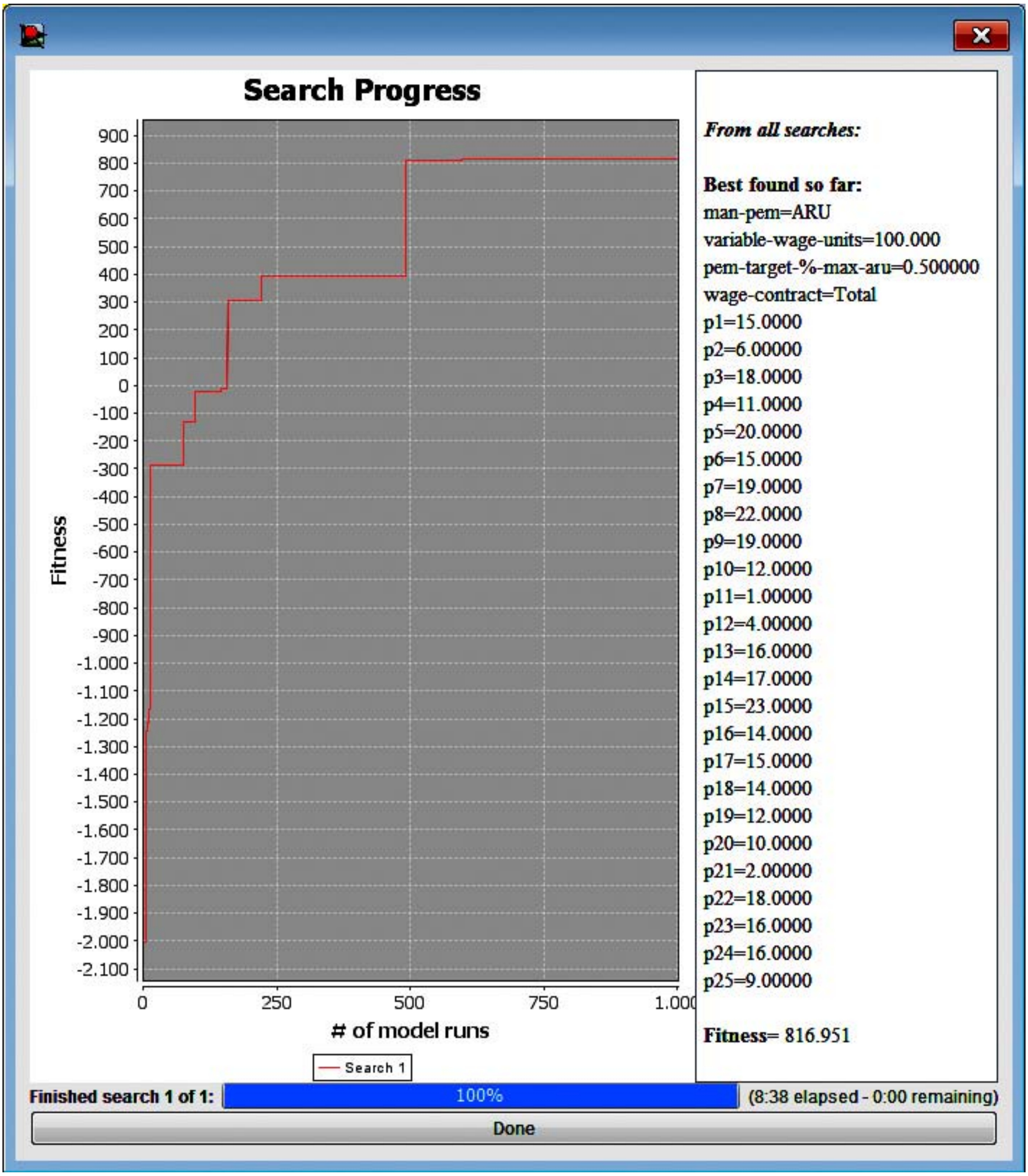


Figure 9 – Experiment 1 – BehaviorSearch – Owner Search Results

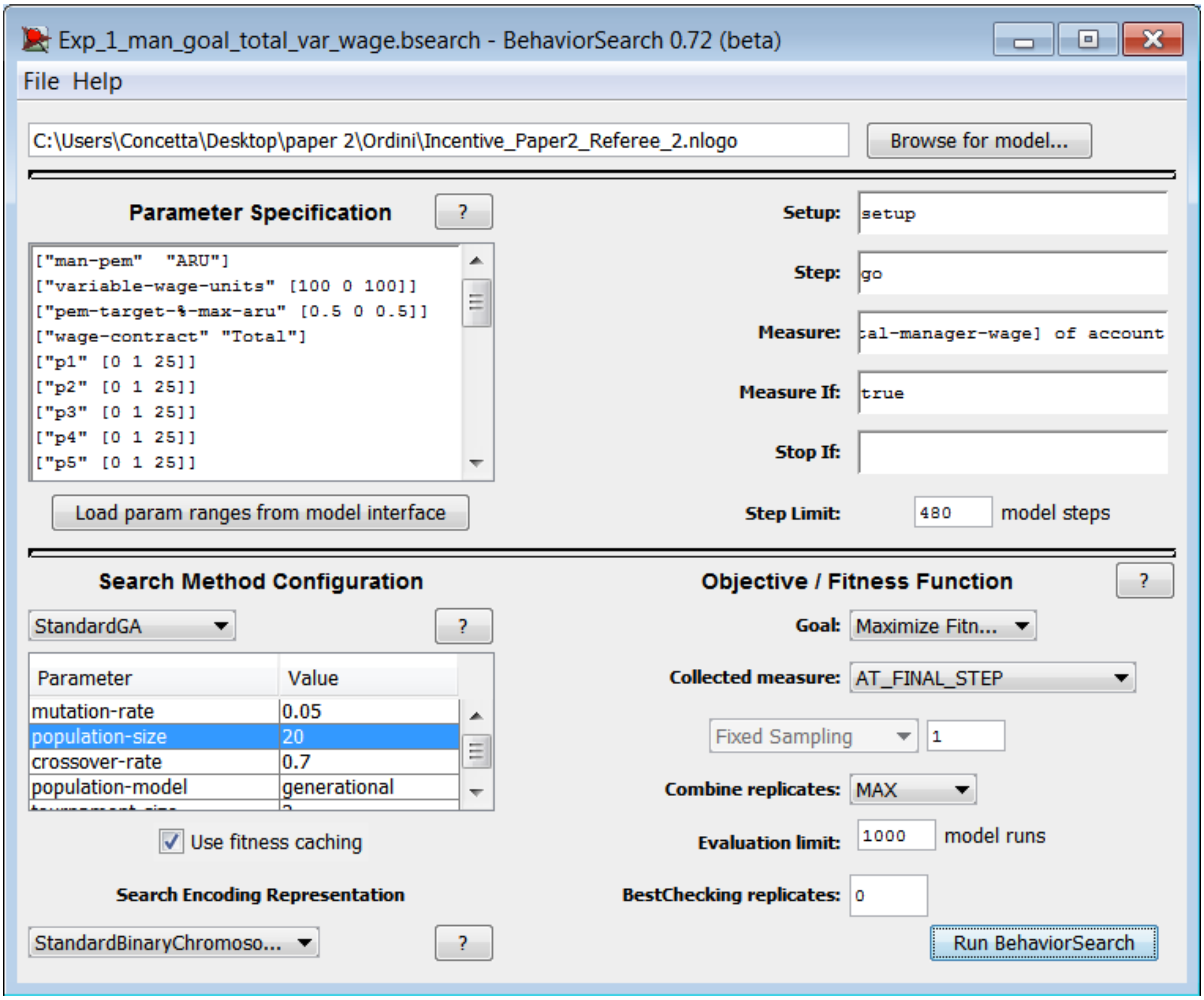


Figure 10 – Experiment 1 – BehaviorSearch – Manager's Search Settings

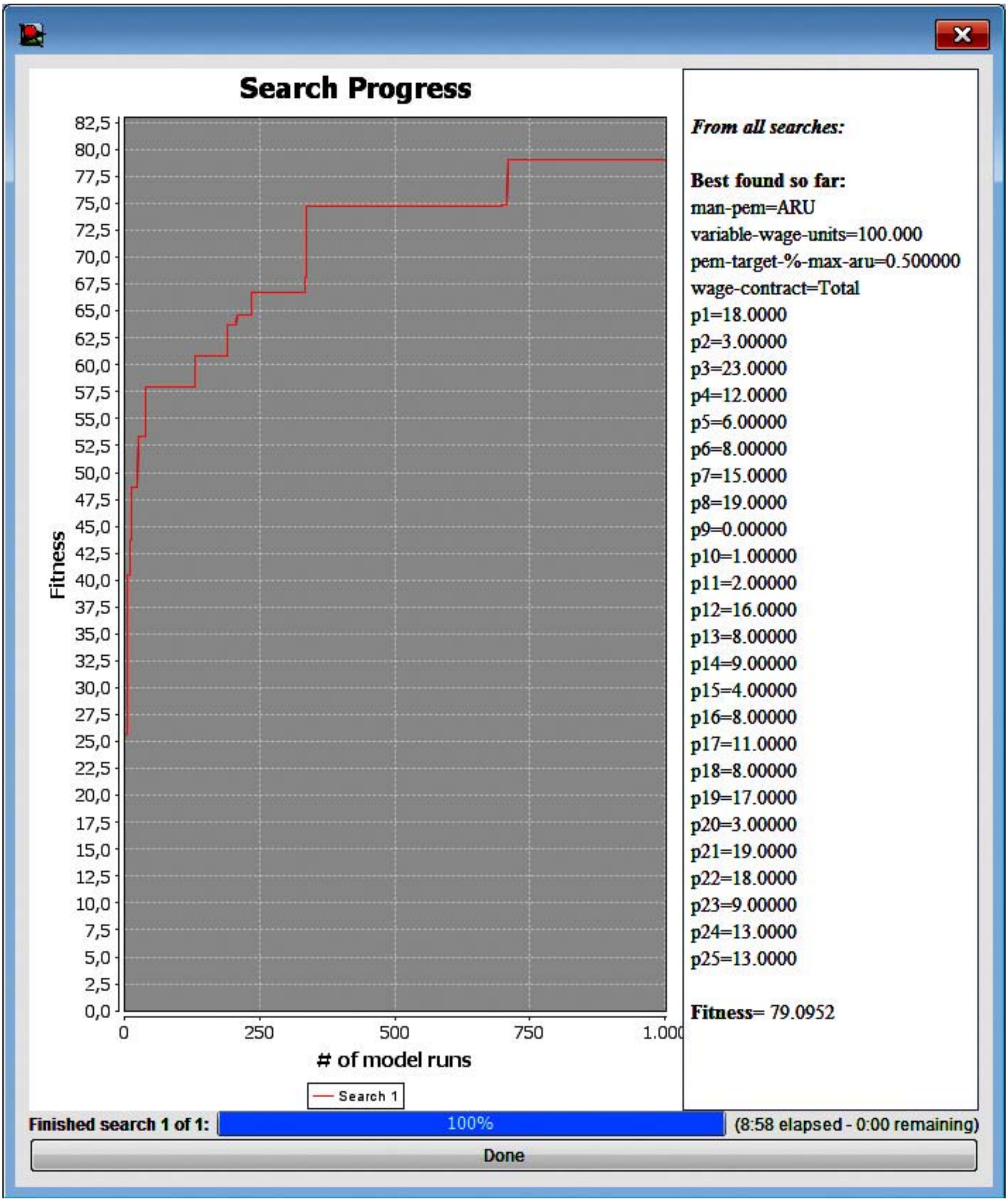


Figure 11 – Experiment 1 – BehaviorSearch – Manager's Search Results

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