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A COMPARISON AND INTEGRATION BETWEEN PRIVATE AND PUBLIC SECTOR THROUGH SUSTAINABLE ECONOMICAL DEVELOPMENT OF THE ROMANIAN RURAL AREAS USING BEE ALGORITHM

George GRUIA[1], George Cristian GRUIA[2]

[1] Spiru Haret University, Faculty of Juridical, Political and Administrative Sciences, 24 Berceni Road, Sector 4, Bucharest, Romania, Email: g.gruia1@yahoo.ro

[2] Czech Technical University in Prague, Czech Republic, Email: cristian.gruia@email.cz

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Abstract

The article is focused on presenting a comparison of the public sector with its public administration policies and private sector with its economical strategies, with the purpose of the better integration between the two, with case study on the European funds in beekeeping and how, by studying the bee behaviour, we too can develop our society to achieve better results. The scope of the article is to show an overview of the European policies into state members with focus on sustainable economic development of Romanian rural areas. This is part of the authors' research from the last 10 years, with focus on public, economic and social development and represents the initial results of their yet not published work.

Keywords: *development; sustainability; Romanian; bee; rural; private sector.*

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Introduction

The present article is focusing on showing how we can improve our society in the urban and rural areas specifically if we learn from the bee's way of living and their tasks within a hive. In other words, we are focusing on a comparison between the public sector, with the rural areas specifically, but not limited to, with the administration policies, and the private sector, with enterprises where all the tasks are done just in time according to the bee algorithm, with the purpose of increasing productivity and competitiveness of the final goods and services. We have conducted an empirical study with a focus on the beekeeping sector which was funded through European programs of development for state member countries, in our case Romania.

We consider this area of great interest for the development of rural areas and increase and sustainable growth of wealth and social development because by simply observing nature and the bee colonies, one can learn and apply the knowledge, through comparison and synthesis to their daily activities. This activity thus becomes an easily accessible tool for improving one's life, no matter of their working conditions and place, whether it is in the public or private sector. Everything started from a small project developed during the author's spare time and slowly it became a larger project where social and economic inputs were added to get an output which can be used as a model for public administration and privately-owned companies. The idea behind this model is the answer to the following questions, where by "company" we consider a state or privately owned company:

1. How can a company improve its processes with the available resources and decrease its indirect costs?
2. How can the company increase its work productivity and its outputs with better quality?
3. How can we develop and sustain this long term development in the rural areas specifically, without any additional training of the people and with minimum costs?

Starting from these Research Questions and from the bee colony's life, with the help of the mathematical models, a new path was found in the development of companies in Romania, with applicability into all the other EU state members, with an adjustment into the implementation methodology based on the specifics of the society and population's social status. By comparing the bee algorithm, where each worker is considered a bee and the task to be completed is considered the "honey", we can extrapolate from the productivity of bees into a colony to the specifics of the processes within the public state apparatus and within the private sector. A specific task which a worker, employee or public servant must complete is made of several sub-routines and if we analyze the big picture we can divide and optimize these processes so as to increase the quality of the output, without increasing the resources (input). This analogy is part of our hypothetical model which is in the initial stages of development and a reason for which, in this paper, we will present only the overview of the problem and the initial part of our research.

Literature Review

In the specific literature we find the bee algorithm, which is the mathematical algorithm developed from the observation of the bees' life and which is used within several mathematical models to find optimum. Bees, like ants and other insects, are social insects and have an instinct ability known as swarm intelligence, which enables them to solve complex problems of the group, beyond the capability of individual members, by functioning collectively and interacting with each other amongst members of the group [Nakrani & Tovey, 2004; Teodorovic & Dell'orco, 2005]. For the honeybees, this intelligence is crucial due to the complexity of finding flowers and collecting nectar and pollen, in a relatively short period of time, related to the life of a honeybee.

The honeybee algorithm has been used in other scheduling problems like Job Shop Scheduling [Chong, 2006], but it wasn't used for parallel machine scheduling with the quality approach.

Rebai (2012) as well introduced a function for total costs, but nothing is mentioned about the quality of the work. Other authors such as Swink (2006) work under the assumption that the time–cost trade-offs for project activities are linear, an assumption we are considering as well in this article. An analogy is made between the working bees from a hive, which have to get out of the hive and search for new flowers, and parallel machine scheduling, by one of the authors in his Ph.D. dissertation thesis [Gruia, 2014].

Romanian Rural Environment: Short General Presentation

In terms of economic development, Romania is in a modest position in the EU, the share in European GDP in 2012 being only 1%. Even though GDP per capita has seen an upward trend after 2010, however, compared to the EU average in terms of

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Standard Purchasing Power Parity (PPS) per capita, it represents only 49%. In this context, investment and competitiveness in Romania are still elements that need to be improved to accelerate economic growth and ensure income convergence with those in the EU. The agricultural sector and the rural economy in general continue to have substantial growth potential, still underutilized. Agriculture generated 30,897.7 million lei Gross Value Added (GVA), representing 6.0% of the total GVA. The evolution of the GVA distribution by sectors of activity reveals a continuous decrease in the share of agriculture in favour of the secondary and tertiary sectors.

Labour productivity in 2012 in agriculture was 2,464 Euro/occupied people, almost 5 times lower than the national average (12,527 Euro/occupied person), while in the secondary sector (industry and construction) and tertiary, the registered values were 1.5 and 1.3 times higher respectively. Rural SMEs involved in non-agricultural activities (industry, services and rural tourism) have a low share. The analysis of micro-enterprises in rural areas highlights their low capacity to respond to the need to provide jobs for the rural population.

The development of small-scale businesses is recognized as the most important source of employment and income generation in rural areas, both for the economies of developed and developing countries. Of the active non-agricultural SMEs at national level, only 18.1% were active in rural areas in 2001. In 2011, the SME density per 1,000 inhabitants at national level was 23.66, well above that recorded average in rural areas, of 9.64 SMEs per 1,000 inhabitants. SMEs' access to finance remains a major problem. From the point of view of territoriality, financial services are generally less accessible to rural businesses and the agricultural sector, with high credit costs (high interest rates on commercial banks for lending, fees and commissions for various services provided by banks). Reducing the number of service workshops and craft cooperatives has led to a severe compression of the rural social economy.

At the same time, the agricultural cooperative sector is underdeveloped, and the tendency is to reduce. In 2005, the number of co-operative units was 108, and in 2010 it decreased to 68 units. Unlike European holdings, Romanian holdings also operate in the productive sphere and not in the field of processing or marketing. Also, as far as practicing traditional crafts (handicrafts, crafts) by craftsmen working on their own or organized in craft associations and cooperatives, in 2010, from 2017 holdings, 42.5% were holdings of craftsmen.

The level of education of the rural population has improved, but at a slow pace. In this respect, the following are relevant:

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−Regarding the school drop-out rate in rural areas, it reduced moderately at all levels of education, but it still remains higher in relation to the urban environment, especially in secondary level education (15.2% in rural areas compared to 5.9 % in urban area in school year 2011/2012);

−The number of specialized agricultural high schools registered a downward trend in the last decade, together with the decrease in the number of graduates (from 2,511 in 2005 to 2,328 in 2011);

−The low attractiveness of the agricultural sector and also the decrease in the number of graduates of the agricultural schools are factors that have contributed to the decrease of the training level of the managers of agricultural holdings;

−Continuous formation and training is at an early stage of the event, which places Romania at a lower level in the EU (1.3% of the rural population in 2010 and 1.6% in 2011 compared to the EU-27 with 9.1% in 2010 and 8.9% in 2011).

At national level, there is a pronounced stream of urbanization of the active population. The economic development of the secondary and tertiary sectors has attracted the active rural population to urban areas in the last decade and in 2012 the urban active population was 11.7% higher than in rural areas, which reveals the need for the development of non-agricultural activities in rural areas. Although the active population in rural areas has a slight downward trend of 1% over the period 2005-2012, against the backdrop of the decline and aging of the rural population, there is still a large available labour force that is currently involved in subsistence and semi-subsistence farming.

In Romania, the employed population is diminishing at both national and rural levels. At the national level, in 2012, the employment rate was 59.5%, lower than the European average by 4.7%. In rural areas, there is a drop in the employment rate from 61.6% in 2005 to 60.7% in 2012. An analysis of the employed population by sectors of activity of the national economy, during the reference period 2005-2012, indicates (-2.6% in agriculture and -4.4% in industry and construction) an increase of 14.5% in the tertiary sector. There are significant disparities in the territorial profile of the occupied population: there are rural localities where the industry or the tertiary sector has minimum values and agriculture accounts for over 80% of the total employment. This is supported by the high employment rate in agriculture of 60.3% compared to the non-agricultural sectors by 40.2% and the industry and services by 40.6%.

Analyzing the structure of the occupied population in terms of professional status, we notice that in 2012, self-employed workers and non-paid family workers from rural areas accounted for 89% of the total population with this professional status.

Also, in the context of the rural economy, their share is 42.6% of the total rural population in 2012, which is associated with subsistence agriculture and lack of alternatives to entrepreneurship. If we relate to the residence environment, we notice that at the level of 2012, the rural employment rate was 51.9%, being 1.5% higher than in urban areas, which instead of reflecting the existence of better employment opportunities, it rather indicates insufficient and lack of employment in this area.

In Romania there are great differences in wealth, opportunity, education, skills, health and in many areas they have intensified over the last decade. In 2011, 40.3% of the population was at risk of poverty and social exclusion, 16.1 higher than in the EU. These differences are of a profoundly territorial nature, with pronounced variations between regions, as well as between urban and rural areas, the share of people at risk of poverty or social exclusion in the rural area accounting for 54.2%. In rural areas, incomes are relatively low, compared to urban areas in 2011, and were 503 euro per rural household compared to 621 euro per urban household. At the same time, the share of income both in cash and in products in agriculture accounts for 42% of total gross income per household in the rural area, while wages are currently around 26%.

Rural areas in Romania are affected by the lack or deficiency of infrastructure, which has a negative impact on economic development and quality of life. The county and communal roads have a length of 67,298 km (10.6% of the modernized national infrastructure) of which 48% are paved and 29% of them are often impractical in rainy periods. Although the length of water distribution and sewerage networks has increased, access to them remains low, only 13.6% of rural localities are connected to the drinking water supply network at the level of 2012.

Successful implementation of the National Rural Development Plan (NRDP 2014-2020) will not depend only on the existence of financial support, but will also depend on the existence of good ideas for new projects that promote the development of rural businesses and rural communities. The National Rural Development Network (NRDN) was established through NRDP 2007-2013, which contributed to the promotion and connection of local actors. The need to reactivate and strengthen a rural community's development network to facilitate the exchange of knowledge, experiences and reanimation of local community actors is essential for an active rural area. And all these development programs cannot be done without the help of the EU and their European Funds for development of EU states which in our specific case is called nationally as the National Beekeeping Program, where beekeepers are helped to acquire medicine, bees, hives, etc. in order for our local Carpathian race of bees to be protected and beekeepers to be able to sustain themselves from this occupation.

Sustainable Economic Development Using Newly Developed Bee Mathematical Model

Based on the doctoral thesis of one of the authors, we also consider, in this article, working and sharing tasks on identical parallel machines as an option for increasing productivity. And this division can be applied easily into manufacturing companies, as well as into public administrations, where several offices are open for delivery or "manufacturing" of the same task and they are working in the same time on "parallel lines", which have a starting point or input; in this case being the citizen who wants an official document and, after being processed by the public servant, the input becomes an output, i.e. the document is officially stamped and delivered to our customer – the citizen.

That is why the applicability of our model is wide and diverse and we can consider each and every task through analogy with the honeybee's production of honey and how, by using their swarm intelligence, they are creating such a complex product, the honey, from several thousand flowers. Even if we can apply the model in all sectors, we shall not forget about the quality of the work, which is actually a necessary condition of our model and also decisive in the productivity increase and sustainability of economic development of the Romanian areas, specifically the rural ones.

The honeybee algorithm has been used in other scheduling problems such as Job Shop Scheduling, but we are not aware of it being used for identical parallel machine scheduling.

An analogy is made between the working bees of a hive, which have to get out of the hive and search for new flowers and parallel machine scheduling. Let H be the set of honeybees searching for flowers and F the set of possible flowers and food sources where a bee can start and finish her job of foraging nectar.

Before defining the mathematical model, some restrictions are applied due to the analogy with the honeybees, which will apply in the article as follows:

- Each working bee has a random defined loading capacity lc_i of pollen and nectar (further referred as "food");
- Each flower in the flower patch should be visited by the working honeybee only once and upon returning to the hive the bee will carry a certain amount of

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food between 0,01 and 1, where 1 is the maximum loading capacity of the bee equal to the maximum amount of available food in the visited flower;

- A flower patch consists of a random number of flowers from minimum 1 to a maximum of the number of all the given flowers;
- The colony is divided into scouts (which is a defined number of 10% from the total number of bees), which randomly search for food, working bees (80% of the population), which wait in the hive for the scouts to return and after getting to the flower, they also become scouts for the flower patch where they were sent initially by the scouts; and onlookers (10% of the population), which stay in the hive and perform maintenance and "final" operations to the final product (honey);
- The scouts, after finding a flower, return to the hive with foraged nectar and pollen and, using the waggle dance, recruit the working bees until all the flower patches are discovered. After that they transform into working bees and according to their visited flowers remain to harvest the flower patch which is the richest in food;
- After unloading the food in the hive, a recovery time *tr* is considered as a sum of: the prepare time *tp*, the bee prepares itself for the second flight (fixed input costs are related with this) and the waggle dance time *td*, in which it shows its findings to the other colleagues, for other bees to follow and forage the flower patch as soon as possible, where $tr = tp + td$;
- A bee can fly only on a maximum 3 km radius around the hive, with an average speed of 30 km/h, that is a forage trip can last at most $(720 + t_f)$ seconds, where t_f is the foraging time;
- Each flower within the visited flower patch is assessed by the onlooker bees with a certain priority or weight w_k according to the duration of the waggle dance of the working bee returned to the hive;
- The jobs are done without pre-emption or re-assignment.

We will further consider only the case of the scouts with working bees in their search for food, because after the flowers are found the foraging operations can be automated and standardized by the other working bees, a schedule not being needed any more to be changed after each operation, but only once at the beginning of the work.

We can characterize each bee by a flying time, defined as eq. (7) and a weight w_k as eq. (5). Each flower is foraged by a certain bee within a certain period of time, i.e. a processing time t_f, which is the same time for all the bees in this particular case, a tardy weight tw_k, an early weight ew_k and an optimistic due date

d_k^o, as well as a pessimistic due date d_k^p and a minimal flying cost fc_i (the amount of pollen and nectar foraged is lower than the actual amount brought in the hive because a part is consumed by the bee according to eq. (14)).

Rebai (2012) introduces a function for total costs, but nothing is mentioned about the quality of the work. We will further consider a similar cost function, but in a different environment. According to our developed MAKEMAX model, we want to improve the quality of the product within the earliest processing time, i.e. the optimistic due date, but due to different factors we have another pessimistic due date, which we want to minimize. From the nectar and pollen foraged, honeybees produce the final product, the honey, and assuming that the available resources are of the best quality in different amounts, and that each bee is "trained" to produce the honey at the beekeeper's quality requirements, we want to measure the quality of the work of the honeybees, which should be at the highest levels and thus we start to measure it from the time $t = 0$, which is the beginning of the working day, for a 12 hours working shift.

We introduce a Bee Preventive Quality Assurance System (BPQAS), so that counteractive measures can be taken in due time in order to solve possible problems and to find the optimal combination from a number of simulation cycles of minimum costs, minimum completion time of the jobs and a maximum quality level of the work and indirectly of the product.

Generally the costs are divided in direct and indirect costs. We further consider in this article the costs related to the individuals' work (honeybees) and we will work under the assumption that the time–cost trade-offs for project activities are linear [Swink, 2006].

When BPQAS is put to work, within an optimistic d_k^o and pessimistic due date d_k^p , the operational cost associated is minimum and is the same as the flying cost fc_i. On the other hand, if the BPQAS is put to work before the optimistic due date d_k^o (which is the smallest amount of time in which the job is fulfilled), we will have a new total cost as follows: $tc_i = fc_i + TR(d_k^o - d_s)$, where d_s is the point ever since we have started implementing the BPQAS.

An explication for this expression can be given, that the bee begins to consume honey before arriving to the flowers, i.e. the worker produces a cost to the company before beginning the work in the so called "dead time" of his work shift.

If the foraging time is greater than the pessimistic due date, the total costs are increasing according to the following relationship: $tc_i = fc_i + TR(d_f - d_k^p)$, where d_f is the actual finish time of the forage and TR is the time rate of the job with the unit RON/s.

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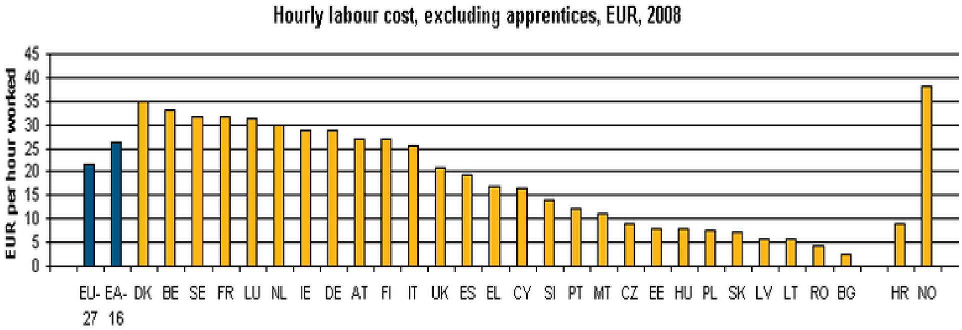
The time rate of a job in the manufacturing industry is taken from the European Union statistics before the economic crisis (Eurostat – Tables 1 and 2) for countries such as Romania and Czech Republic, according to the manufacturing enterprise where we have implemented the algorithm with its Quality Scheduling Index. Due to this fact, one can see the wide applicability of our model in any European country or other country according to the hourly labour cost from that country or region.

Table 1. Labour Cost Structural Statistics



Source: European Commission Eurostat, [online], http://epp.eurostat.ec.europa.eu/ statistics_ explained/index.php/Labour_cost_structural_statistics, accessed 25.07.2013.

Definition 1 – A foraging operation is equivalent to a manufacturing operation and is considered complete when the input (nectar and pollen) is transformed to output (honey).

In order to be able to measure the efficiency of the honeybee's work we introduce the following performance coefficient of the i[th] bee:

$$k_i = \frac{quality\ of\ the\ i-th\ bee}{(processing\ time + recovery\ time) of\ the\ i-th\ bee}$$

where processing time is the time taken for flying away from the hive to the flower, foraging the pollen and nectar and returning to the hive, and together with the recovery time forms the makespan for the manufacturing of the final product, i.e. honey. In this manner we want to obtain big values of the coefficient which can be done in three ways:

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–By increasing the quality of the work (assuming that the available nectar and pollen are of the best quality, i.e. the raw input materials are according to the standards);

Table 2. Hourly Labour Cost, Excluding Apprentices, By Enterprise Size Class

	10 to 49	50 to 249	250 to 499	500 to 999	1000 and more	small vs big enterprises	
						absolute difference	difference in %
EU-27	18.17	19.94	21.26	22.03	24.82	6.65	37%
EA-16	20.72	24.15	26.78	27.79	30.27	9.55	46%
BE	28.45	31.29	34.56	34.44	36.74	8.29	29%
BG	1.90	2.40	2.88	3.49	4.10	2.2	116%
CZ	7.62	8.94	9.41	9.48	10.77	3.15	41%
DK	33.52	36.23	37.53	37.85	34.20	0.68	2%
DE	22.02	24.86	28.53	30.24	35.11	13.09	59%
EE	7.21	8.09	8.95	7.53	8.29	1.08	15%
IE	22.82	25.94	29.55	32.86	35.97	13.15	58%
EL	15.26	15.34	16.98	16.40	20.76	5.5	36%
ES	15.36	18.59	21.28	22.66	23.5	8.14	53%
FR	27.21	30.36	32.07	33.70	34.33	7.12	26%
IT	26.38	25.52	24.26	24.09	26.23	-0.15	-1%
CY	11.58	15.26	16.66	15.39	27.54	15.96	138%
LV	4.48	5.92	6.56	7.90	7.19	2.71	60%
LT	4.93	5.85	6.45	7.04	6.72	1.79	36%
LU	25.87	30.1	33.52	34.20	38.81	12.94	50%
HU	5.54	7.49	8.76	9.22	9.88	4.34	78%
MT	9.32	10.13	11.52	11.16	14.31	4.99	54%
NL	26.28	28.78	31.32	31.47	31.73	5.45	21%
AT	22.66	25.69	28.84	30.66	30.7	8.04	35%
PL	7.36	7.44	6.98	7.36	8.45	1.09	15%
PT	9.12	12.67	13.89	13.96	15.07	5.95	65%
RO	2.61	3.51	4.07	4.33	5.54	2.93	112%
SI	:c	13.84	:c	:c	14.76	:	:
SK	6.62	6.97	7.2	7.46	8.76	2.14	32%
FI	23.15	26.85	28.92	28.57	28.38	5.23	23%
SE	29.24	32.52	34.09	33.79	31.66	2.42	8%
UK	18.21	20.96	23.06	23.18	21.40	3.19	18%
HR	12.31	8.70	8.35	8.93	10.19	-2.12	-17%
NO	32.83	37.89	38.87	39.88	43.56	10.73	33%

Data refer to enterprises with 10 employees or more and to NACE Rev. 2 aggregate B to S excluding O.
: data not available
:c confidential data

Source: European Commission Eurostat [online], http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Labour_cost_structural_statistics, accessed 25.07.2013.

– By decreasing the makespan, i.e. the completion time of the last job in the schedule, but which must correspond to the working conditions and standards (the recovery time cannot be reduced to zero);

– By increasing the quality with the additional decreasing of the processing time.

In this article we focus on the third way of increasing the value of the k_i coefficient and use the symbols below with their unit of measurement:

tc_i	total costs	(RON)
fc_i	fixed costs	(RON)
C_i	completion time	(s)
ew_{ki}	early weight	(-)
tw_{ki}	tardy weight	(-)
w_{ki}	weight within optimistic and pessimistic due date	(-)
lc_i	loading capacity of the bee	(-)
Pf_i	profitability index of the bee	$(s^{-1}.RON^{-1})$
E_{ki}	earliness of the job	(s)
T_{ki}	tardiness of the job	(s)
d_k^o	optimistic due date	(s)
d_k^p	pessimistic due date	(s)
d_s	start time of the job	(s)
d_f	finish time of the job	(s)
t_d	waggle dance time	(s)
t_f	foraging time	(s)
t_p	prepare time for new job	(s)
f_i	flying time	(s)
q_i	quality of the work of the bee defined as a quadratic function of x_i	(s^{-2})
x_i	variable of the quality	(s^{-1})
TR	time rate of the job	$(RON . s^{-1})$
y_{ik}	binary variable	(-)
z_{ik}	binary variable	(-)

Our model is a system of equations where we should increase quality of the work, decrease costs and decrease total makespan of the colony and this can be translated as a minimizing criterion of a ratio, which we denote as a *Quality Scheduling Index*, *QSI*:

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$$\text{QSI} = \frac{\sum_{i=1}^{h}\sum_{k=1}^{f}(ew_{ki}E_{ki}y_{ik} + tw_{ki}T_{ki}z_{ik} + w_{ki}C_i)}{\sum_{i=1}^{h}\sum_{k=1}^{f}\frac{q_i}{tc_i * (E_{ki} + T_{ki} + C_i)}} = min$$

Subject to:

$$E_{ki} = \begin{cases} d_k^o - d_f, d_k^o > d_f \\ 0, \ otherwise \end{cases} \quad (1)$$

$$T_{ki} = \begin{cases} d_f - d_k^p, \ d_f > d_k^p \\ 0, \ otherwise \end{cases} \quad (2)$$

$$ew_{ki} = \begin{cases} (priority\ according\ to\ rule\ X) + 1, \ C_i < d_k^o - d_s \\ 0, C_i \in [d_k^o; d_k^p] \end{cases} \quad (3)$$

$$tw_{ki} = \begin{cases} (priority\ according\ to\ rule\ X) - 1, \ C_i > d_k^p - d_s \\ 0, \ C_i \in [d_k^o; d_k^p] \end{cases} \quad (4)$$

$$w_{ki} = \begin{cases} priority\ according\ to\ rule\ X, C_i \in [d_k^o; d_k^p] \\ 0, \ otherwise \end{cases} \quad (5)$$

$$C_i = f_i + t_p + t_d, where\ C_i \in [d_s; d_f], \ \ t_p \in \left[\frac{f_i}{4}; \frac{f_i}{3}\right], \ \ t_d = \frac{f_i}{10}, t_f \in [d_s; d_f] \quad (6)$$

$$f_i \in [t_f, 720 + t_f] \quad (7)$$

$$y_{ik} + z_{ik} = 1, \forall\ i = 1,2, \dots, h\ and\ k = 1,2, \dots, f, i \neq k \quad (8)$$

Taking into consideration the experience from the workers production lines, we define the quality as a quadratic function, with the variable x_i, taking the following form:

$$q_i = x_i^2 + x_i + 1 \text{ , where } x_i = \sum_{k=1}^{f} priority_k\ lc_i\ \frac{1}{C_i} \quad (9)$$

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and $i \in \{1, 2, \ldots, h\}$ *is the set of honeybees and* $j \in \{1, 2, \ldots, f\}$ *is the set of available flowers on a radius of 3km around the hive*

The loading capacity of the i[th] bee is defined as $lc_i \in (0; 1]$ (10)

The overall quality of the work of the honeybees should not exceed 3.4 defects per million opportunities, according to the 6σ level. Thus, after computing the minimum of the stated above function, different quality levels with corresponding total costs and makespan are analyzed using graphical representation and using regression and correlation analysis, we find the trend of our data with the purpose of seeing how the distribution looks like within the upper and lower limits, which in our case are the optimistic, respectively the pessimistic due dates of the foraging jobs.

The priority of each flower is function of the waggle dance, which at its turn is a function of the dancing time on the dance floor. But also prioritizing the flowers which are to be foraged increases the chance of profitability of the individual and of the colony. In this consideration, according to the priority from the waggle dance, each bee assesses the flower visited before the dance and after looking at the new source of food, showed by its colleagues. Thus, the weight of a foraging job is divided into normal, early and tardy weight, which are assessed together and correspondingly a new set of priority is set for the bee, before engaging in another foraging expedition.

We use two binary variables y_i and z_i:

$$y_{ik} = \begin{cases} 1, for\ E_k > 0 \\ 0, otherwise \end{cases} \quad (11)$$

$$z_{ik} = \begin{cases} 1, T_k > 0 \\ 0, otherwise \end{cases} \quad (12)$$

$$\begin{cases} tc_i = fc_i + TR(d_k^o - d_s), for\ t_f \in [d_s; d_k^o] \\ tc_i = fc_i, \quad for\ t_f \in [d_k^o; d_k^p] \\ tc_i = fc_i + TR(d_f - d_k^p), for\ t_f \in [d_k^p; d_f] \end{cases} \quad (13)$$

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$$fc_i = 1\%\ lc_i \qquad (14)$$

Equations (1) and (2) define the earliness and tardiness jobs, as a function of the finishing time and the optimistic, respectively pessimistic due date, which are defined as two distinctive intervals in time.

Taking into consideration that the total costs decrease until the optimistic due date, remain constant until the pessimistic due date and then increase if the finishing time is bigger than the pessimistic due date, we assign tardy weights and early weight in such a way that we want to postpone as much as possible the finalization of a job with earliness, but on the other hand to speed up the finalization of the job with tardiness, as shown by eq. (3) and (4).

The ***Rule X*** is given by the Corollary 1, stated below. Thus eq. (3), (4) and (5) must comply with Corollary 1, i.e. if $ew_k = tw_k = w_k$, the jobs will be scheduled as follows: $w_k > tw_k > ew_k$.

Equation (14) states the fixed costs as a fixed percentage of the loading capacity of the bee. According to Chong (2006), a forager is more likely to randomly observe and follow a bee's waggle dance on the dance floor if the profitability rating is low as compared to the colony's profitability.

Table 3. Priority for the Forager Bee

Profitability rating	Probability of following the waggle dance	Priority for the forager bee
$Pf_i < 0.9Pf_{colony}$	0.60	4th
$0.9Pf_{colony} \leq Pf_i < 0.95Pf_{colony}$	0.20	3rd
$0.95Pf_{colony} \leq Pf_i < 1.15Pf_{colony}$	0.02	2nd
$1.15Pf_{colony} \leq Pf_i$	0.00	1st

Source: Adapted from Nakrani & Tovey, 2004

The bee can choose only from a list of 4 possible flower patches according to the initial memorized source food, the bee itself found, and after following the waggle dances of its colleagues, other bee workers. In the case in which the probability of following the waggle dance is equal to zero, the bee doesn't stay to dance another round and continues with the foraging of the initial food source, which it found.

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However, in our case, we aim at introducing and maintaining the quality of the produced product, thus we define the profitability index for a bee as follows:

$$Pf_i = \frac{1}{tc_i * C_i}$$

and the profitability index of the colony as:

$$Pf_{colony} = \frac{1}{h}\sum_{i=1}^{h} Pf_i,$$

where C_i is the completion time of one bee measured between two consecutive flights, assuming that every time it performs the waggle dance.

It was considered the case when the working bees are working in a single 12 hours shift and accordingly the minimum for flying time is 1 second and maximum for completion time is 43,200 seconds.

Lemma 1: For a given number of m jobs which are to be sorted, according to n vector defined constraints, there exists a schedule where the 1^{st} job has the n^{th} constraint the same or belonging to the same set of vectors n or combination of them, with the rest of the (m-1) jobs; the 2^{nd} job has the (n-1) constraint, the same or belonging to the same set of vectors with the rest of the (m-2) jobs, etc.

Proof: The proof is rather trivial, and we will try to show it in a simple example. There are given m = 4 jobs and n = 3 constraints, i.e. total costs, completion time and quality of the job. Then, for random values of these constraints between 1 and 10, we can choose a way of job sequencing according to our constraints as follows:

1^{st} job – TC = 4, C = 2, Q = 7;
2^{nd} job – TC = 3, C = 4, Q = 5;
3^{rd} job – TC = 7, C = 3, Q = 8;
4^{th} job – TC = 1, C = 1, Q = 10.

The flowchart of my algorithm is presented below in Figure 1.

If we sort after the first constraint, minimum total costs, we have the following sequence:

$$4 \rightarrow 2 \rightarrow 1 \rightarrow 3$$

If we sort after the minimum completion time, we have:

$$4 \rightarrow 1 \rightarrow 3 \rightarrow 2$$

If we sort after the maximum quality level of the jobs, we have:

$$4 \rightarrow 3 \rightarrow 1 \rightarrow 2$$

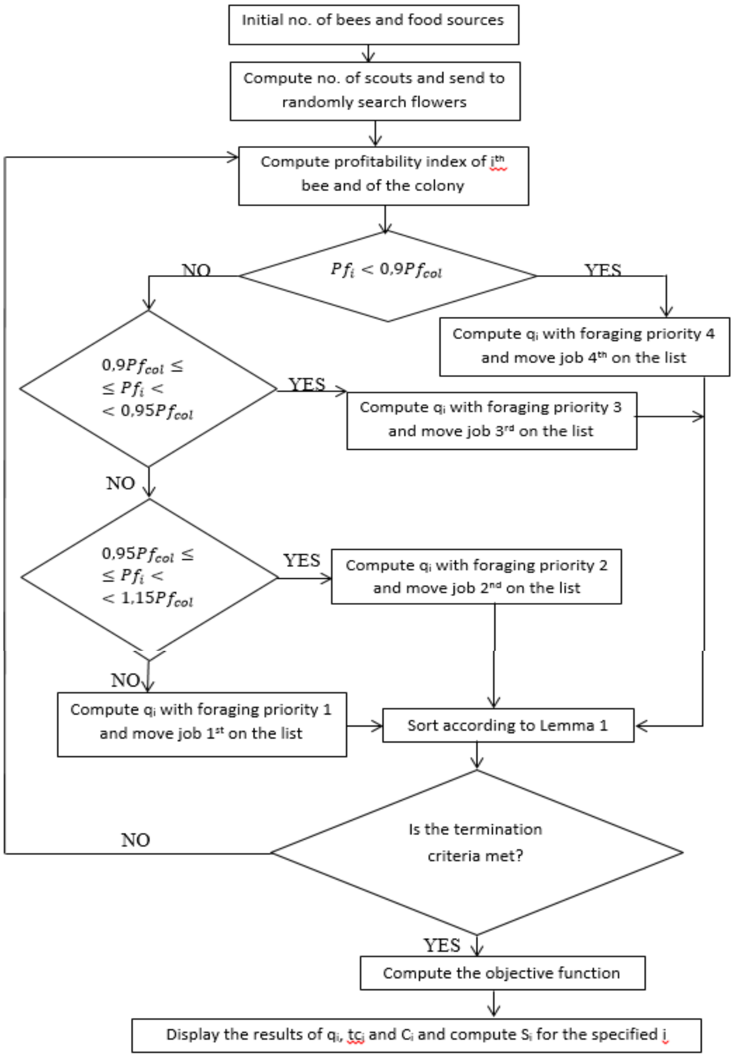

Fig. 1. Flowchart of Bee Algorithm
Source: Gruia, George Cristian, *Design of Experiments in Scheduling Scenarios for Workload Distribution and Qualitative Usage of Time*, Ph.D. diss., Czech Technical University in Prague, 2014.

We can see that the 4th job should be done first, then we can see that, in 2 out of 3 existent cases, 1st initial job should be done 3rd and 2nd initial job should be done last. Finally the 3rd initial job can be successfully made 2nd and the sequence after our rule X will be:

$$4 \to 3 \to 1 \to 2$$

In case we will have different values on each of the columns of the three lines after we've sorted the values after minimum total costs, minimum completion time and maximum quality, the rule for assigning will be according to the maximum value of the following ratio of our vector constraints $\frac{q_i}{tc_i \cdot C_i}$ for each ith bee.

Corollary 1: If the weight of a job J_i with finishing time between the optimistic and pessimistic due date is the same as the early weight or tardy weight of different previous or later job, priority will have the job J_i, followed by the job with tardiness and finally the one with earliness.

Conclusions

In the article presented above, the authors have showed initial results of their research where, if we manage to schedule jobs or tasks from public administration apparatus and/or privately held companies according to the bee's algorithm, where the inputs are the workers and available resources (here presented as flowers and bees) and if we consider that all the workers know exactly what is their purpose and role within the company, then the output (honey) will be done in a Just In Time manner, where quality of their work and time spent on every operation plays a strategic and critical role, which differentiate sustainable increase in productivity from losers on the market and in the face of the citizens (for public administration apparatus).

The article was developed starting from the analogy between bees and how one can easily observe and learn firsthand from the bees and by dividing their work and daily activities together with team work, with a focus on quality, the rural community can develop, based on the presented mathematical model, a methodology with the scope of improving an area's productivity and sustainability of the economic development of those areas. We wanted to focus on Romanian rural economic development, however the applicability of the model can easily be broadened on urban areas also, where the private sector has strong interests and last, but not least, we can implement it at a European level through some European directives and norms. We wanted to show that starting from nature observations people can easily learn and apply the knowledge in their daily activities and the same as the bees to be able to create complex products (honey) with so little available resources and all thanks to the optimization of work and quality of the time spent in doing our business.

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