DISTRIBUTION CENTER OPTIMUM LOCALIZATION AND THE GRAVITATIONAL MODEL

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Abstract:
The present paper approaches the issue of identifying the most suitable position of a distribution point in order to make it attractive and accessible to most "power centers" (sources of potential buyers, donors, etc.), starting from the gravitational model used in Physics. Our study took into account Railly's formula into which an additional variable was introduced, namely, the land price in the area at a certain distance from the power centers. The results present deviations from the calculated distances according to Railly's formula, in the sense that they get closer to the minimum price area.

Key words: gravitational model; attraction; distribution center; distance; land price

1. Introduction

In order to start or develop a business, the current practice is to first take into account the potential of the space area where it is destined to lie by analyzing together the data related to the respective area and the type of commercial activity (the industry which the investment is destined to). Certainly, the analysis must deal with parameters related to population (unemployment, wage levels, etc.), weather conditions, infrastructure and so on. For the purpose of being more efficient we choose to focus on the starting condition, namely, the one related to the space area in which the business is to develop. Throughout this paper we aim to demonstrate that one way to reach optimum results regarding this issue is by appealing the experience demonstrated in Physics.

Following experiments based on bodies being attracted towards the earth surface, Physics demonstrated that all bodies attract each other with a certain force. In the case of small bodies usually used in experiments, the reciprocal attraction based on gravitation is so reduced that very sensitive instruments are necessary. On the contrary, the action of gravitation on big bodies is extremely high especially if one of the bodies is Earth, a particular case of the universal attraction phenomena (Newton 1687).

2. Variables and relationships in attraction process

The gravitational model proves to be a very productive approach in solving certain regional trade, industry and logistics problems. According to it, the interaction intensity between two entities is determined by their dimension or importance as well as by the distance between them. We consider that the dimension of population migration from place *i* to place *j* can be represented as a function of the population in each of the two places and the distance between them. Of course, other factors such as economic development, labor market, problems related to communication in each of the two locations, etc. are considered not to interfere. A general representation of the gravitational model is:

$$I_{ij} = \frac{A \cdot P_j^{\alpha} \cdot P_i^{\beta}}{D_{ij}^{\gamma}} \quad (1)$$

where: I_{ij} = the size of the interaction between positions *i* and *j*

A = the constant

P = a variable such as population (number of inhabitants) or income

D = distance between *i* and *j*;

α, β, γ = parameters

A different variant of the gravitational model (Railly 1958) includes the same factors, namely, population and distance, having the following formula:

$$\frac{aA}{aB} = \frac{P_A}{P_B} \cdot \left(\frac{D_B}{D_A}\right)^2 \quad (2)$$

where: aA = attraction to A

aB = attraction to B.

P_A = population of A

P_B = population of B

D_A = distance from the new store to A

D_B = distance from the new store to B

An equal attraction to the store of the population in A and of the B one respectively implies that the ratio on the left side of the equality (2) will be equal to 1, so that:

$$1 = \frac{P_A}{P_B} \cdot \left(\frac{D_B}{D_A}\right)^2 \quad (3)$$

We make use of the gravitational model by introducing the attraction oriented towards the distribution point (store, retail shop, donation center, meeting place, etc.) at a distance which would make it accessible (attractive) to as more power centers as possible. All throughout the analysis we name *power centers* the sources of people likely to acquire, donate, show themselves, etc. In our following application we quantify attractiveness in relation to distance and to the number of potential clients (population).

The relation Railly put forward approaches attractiveness from the perspective of the distribution unit owner, focusing on his / her interest to gain access to several markets.

In our case, we particularly wish to attract as many clients as possible on two market represented by two urban centers different in terms of the level of population. Regarding this model, we notice that the presence of several variables is obvious, such as each city's attraction, the distance to the distribution point, the city size in terms of population. However, their number has been drastically reduced by introducing the condition of being equally attractive, therefore, in ratio equal to 1. Furthermore, in case the distance between the towns is known, it is sufficient to determine the distance to the distribution point from one of the two localities. Therefore, the existence of only one unknown (noted by x), namely the distance between one of the localities and *the new store*, has lead to reducing the model to only one equation. The fact that attraction is directly proportional with the population of the respective town and inversely proportional with the distance is according to reality.

3. Application

In the first variant of the application we choose to take into account the latter relation (3) in order to solve the concrete problem of the company PROFILO-METAL Prodcom Ltd., a buliding materials store located in Ploiesti. The owners plan to move and extend their activity in an optimum way to other urban areas, especially towards Bucharest. As follows, in such a location the so called *new store* will be situated.

Starting from the company's needs, which were communicated to us by the administration, we shall start our analysis by placing the *new store* somewhere between Ploiesti and Bucharest so that it is attractive to both centers.

As follows, we take into account the statistics of the last census published on *www.recensamantromania.ro*: P_A = 197,522 inhabitants, P_B = 1,677,985 inhabitants; as well as the data recorded on the website *www.distantarutiera.eu* related to the distance between cities A and B: D = 60.8 km. In order to calculate the distance to Ploiesti necessary for determining the optimum location of the *new store*, we note: $D'_A = x$, respectively $D'_B = D - x$.

In equality (3), if we replace $D_A = x$ and $D_B = D - x$, the possiblility to obtain the optimum distance *x* results as follows:

$$x = \frac{D\sqrt{\frac{P_A}{P_B}}}{1+\sqrt{\frac{P_A}{P_B}}} \tag{4}$$

Therefore, we have: $x = \frac{60.8\sqrt{\frac{197,522}{1,677,985}}}{1+\sqrt{\frac{197,522}{1,677,985}}} = 15.53$ km

Accordingly, the optimum location of the *new store* is 15.53 km from Ploieşti and 45.27 km from Bucharest.

In the same way, we apply the same method to the other important cities close to Ploieşti, namely, Targoviste, Brasov, Buzau si Slobozia. The data are gathered in the table below:

Table 1. Descriptive information

	City	Distance to Ploiesti (km)	Population	Optimum location from Ploiesti (km)
1	Bucharest	60.80	1,677,985	15.53
2	Targoviste	49.40	73,964	30.65
3	Brasov	110.00	227,961	53.03
4	Buzau	74.50	108,384	42.80
5	Slobozia	124.00	43,061	84.53

As a result of the analysis, it can be noticed that the optimum location of the *new store* is closer to the town with less population according as the ratio of the two towns population increases.

4. Land price and adjusted optimal distance

As follows, we aim to extend the analysis by including additional factors. Concretely, we shall introduce the *land price* in the area lying at determined distance (*x*) and the minimum price of the land between the two analyzed localities. This time too, attractiveness is obviously approached from the perspective of the distribution unit owner. The result is a certain distance (*x'*) which is sensitive to an additional important element, price. This can be the land price as such or rent, to which expenses (e.g. transport expenses) can also be added, an increasingly efficient solution being obtained in this way.

Hypotheses:

- Price (in the sense of rent) stands for a variable which increases the closer we get to each of the two towns
- Price can be known, being minimum at a certain distance between the two towns ($D_A^{(p_{\min})}$, $D_B^{(p_{\min})}$) and presenting increase rates calculated as opposed to the minimum price, so that a symmetrical evolution can be noticed as we get closer to each of the two localities in focus

For example, we can identify a minimum price area on the axis Ploiesti – Bucharest, at a distance $D_A^{(p_{\min})}$, not necessarily in central position. Our proposal is to include the variable into the calculus as a coefficient multiplying the determinate distance (*x*) from [4]. The coefficient is represented by the square root of the ratio between the land price situated at distance (*x*) to the minimum price if *x* is smaller than $D_A^{(p_{\min})}$, respectively the square root of such ratio if (*x*) is higher than $D_A^{(p_{\min})}$.

Therefore, the relation has the following form:

$$x' = x\sqrt{\frac{p_x}{p_{min}}}, \text{ if } x < D_A^{(p_{\min})} \quad (5)$$

$$x' = x\sqrt{\frac{1}{\frac{p_x}{p_{min}}}}, \text{ if } x > D_A^{(p_{\min})} \quad (6)$$

$$x' = x, \text{ if } x = D_A^{(p_{\min})} \quad (7)$$

where:

x = distance from [4]

p_x = price in the area at distance *x*;
p_{min} = minimum land price on the axis between the localities in focus;
x' = adjusted determined distance (in the sense of sensitivity to land price)

The results obtained by using formulae (5) – (7) are presented in Table 2.

Table 2. Computation outcomes

	Town	Distance to Ploiesti (km)	Population	Optimal positioning from Ploiesti (km) (x)	Land price at determined distance	Minimum price	Distance between Ploiesti and minimum price area	Adjusted determined distance (km) (x')
1	Bucharest	60,80	1.677.985	15,53	4	3	20	17,93
2	Targoviste	49,40	73.964	30,65	2,5	2,5	30	30,65
3	Brasov	110,00	227.961	53,03	7	6	40	49,10
4	Buzau	74,50	108.384	42,80	3	2	60	52,42
5	Slobozia	124,00	43.061	84,53	1,8	1,5	110	92,60

Adjusted determined distances (*x*') (Table 2) present deviations from the initially calculated distances (*x*) in the sense that they get closer to the minimum price area.

As expected, in the case in which the minimum price on the axis between the two localities in focus is the same with the price in the optimum area determined by calculation, then the adjusted determined distance (*x'*) is the same with the determined optimum distance (*x*). This is the case of the analysis in second position in the table, namely that for the axis Ploiesti-Targoviste.

5. Concluding remarks

Physics has been a continuous source of inspiration for economists in the last centuries and its recent developments open the door to new possible approaches in Economics. The formal side of Physics represents an example for Economics especially with regard to the search for constant values (coefficients) and the attempt to describe phenomena by means of ecquations, including model ellaboration. Taking into account the particularities of each subdomain, economists took over the concepts and laws of Physics in view to analyze economic processes as accurately as possible.

The analysis presented throughout the present article started from the gravitational model introducing attractiveness oriented towards the distribution unit (store, retail shop, donation center, meeting point, etc.) located at such a distance that would make it accessible (attractive) to as many *power centers* as possible. The results of the research point out that the optimum location of the store is closer to the town with less population according as the ratio of the two towns population increases.

Following the introduction of the price variable for the areas analyzed on each of the axes, deviations from the initial results were obtained. The maximum deviation is 22,4% in the case of Ploiesti–Buzau route and the highest deviation axis between the minimum price and the average land price is 50%.

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