

## OPTIMIZATION OF THE CHOICE OF TECHNOLOGY WITHIN THE SPATIAL ORGANIZATION OF PRODUCTION

Jerzy STADNICKI

Kielce University of Technology; yurijs@tu.kielce.pl, ORCID: 0000-0001-7760-1347

**Abstract:** The main objective of the article was to improve the choice of the optimal variant of production technology by taking into account the factor of space. When selecting the optimal system of production technology for a specific good within the limits of a space, a two-stage procedure will be appropriate. The first stage consisting in the selection of technologies optimal for each site from a created list of possible production sites, which technologies, already assigned to a specific site, should be compared with each other by means of economic indicators - spatial competition of technology. The second stage will consist in the assessment, according to the criterion of market size, of those possible production sites already associated with the optimal production technology that were considered prospective in the first stage. Since different technologies can be optimal in different sites, the selection of the optimal production sites will also be the choice of the optimal technologies. In our opinion, this is the only way to guarantee the appropriate justification for the choice of optimal production technology systems for a specific good.

**Keywords:** goods, possible production sites, location factor, spatial competition of technology, selection of optimal technologies.

### 1. Introduction

The right choice of technology for the production of goods increases the competitiveness of companies. Therefore, the improvement of the theoretical aspects of justification of the choice of technology for the production of goods is an important scientific task. There is a lot of publications on justifying the choice of the optimal technology option (Vlachy, 2017; Zhou, 2016; Michalski, 2015; Guzik, 2009; Bouasker, 2012; Damodaran, 2002; Antonelli, 2003; Malerba, 2005; Ghahremani, 2012; Habakkuk, 1962; Proctor, 1992; Łunarski, 2008; Tipping, 1995; Feldman, 1999; Boer, 1999; Kosmalski, 2012; Yeomin, 2002; Solow, 1957; Chiesa, 2005; Ruttan, 1997, 2001; Hitchner, 2006; Park, 2004; Boer, 1999). Despite a huge amount of research on various aspects related to justifying the choice of the optimal technology variant, spatial aspects have traditionally been beyond the researchers' attention. As quite rightly pointed

out by world-famous scholar Mark Blaug, a renowned authority on the history of economic thought, classical and neoclassical economic theories were limited to the study of a "country of miracles, devoid of spatial characteristics" (Blaug, 2000). The economic theory of spatial development and especially the theory of location of business facilities developed as early as the 19th century, but this was done in almost complete isolation from the main trends of economic science - "classics" and "neoclassics". According to Mark Blaug, until 1950, the mainstream of economic science was limited to the analysis of economic phenomena without their spatial characteristics (Blaug, 2000). In terms of the economic justification for choosing optimal technologies for the production of goods, the spatial factor is neglected even today.

Therefore, the main objective of the article was to improve the choice of the optimal variant of production technology by taking into account the factor of space. The choice of the optimal technology for the production of a good may be made under the condition of a pre-determined place of production in space, but such an approach is conceptually wrong, because it ignores the "place – optimal technology" interdependence. Such an approach ignores the fact that not only does the choice of production technology depend on the location of the production site, but also the choice of production site depends on the planned technology. For this reason, when selecting the optimal system of production technology for a specific good within the limits of a space, a two-stage procedure will be appropriate.

## **2. Stages of selecting an optimal system of production technology for goods**

Stage 1, consisting in the selection of technologies optimal for each site from a created list of possible production sites (PPS), in which technologies, already assigned to a specific site, should be compared with each other by means of economic indicators – spatial competition of technology. The implementation of stage 1 requires the following actions to be taken in the next steps:

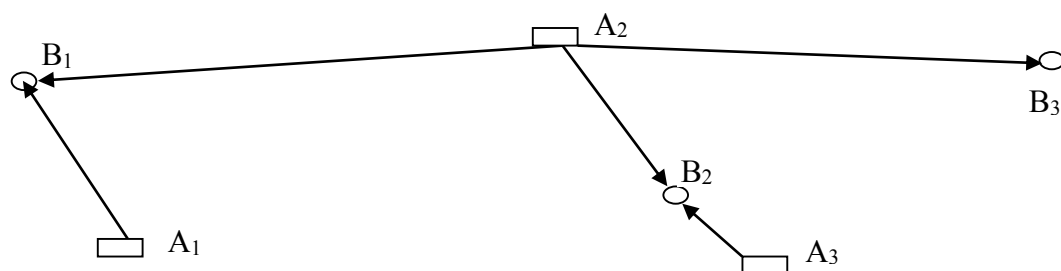
- Determining the boundaries of the space to be analyzed;
- Creation of a list of PPSs for the considered type of goods within the already established boundaries of the space;
- For each PPS, a list of possible technologies for the production of goods should be prepared;
- The list of possible technologies justifies the choice of the technology optimal for each PPS-technology competition in PPS;
- The selected optimal technologies for the respective PPSs should be compared with each other by means of economic indicators – spatial competition of technology;

- Those PPSs which did not lose out in the spatial competition of technology during the selection process in the previous step, are now considered to be prospective for the production of the selected good, and thus proceed to the evaluation in step 2.

Stage 2 will consist in assessing, according to the criterion of market size, those PPSs already associated with the optimal production technology that were considered prospective in stage 1. Stage 2 consists of activities carried out in successive steps:

- Establishment of market zones for prospective PPSs (selected in stage 1);
- Estimation of the demand for the produced good in the pre-determined market zones of each PPS, combined with an estimation of the optimal production capacity of the plant;
- Evaluation of prospective PPSs, according to criteria related to the size of the market, as a result of which, the positively rated PPSs will now be recommended as target production sites (TPS).

Since different technologies may be optimal in different sites, the proposed procedure of analysis of possible production locations allows to properly justify the creation of an optimal group-space system of technology-place of production of goods pairs. Such a group-space approach is correct, because otherwise it would be possible to justify the choice of the optimal production technology for a place where production is not worthwhile. This can be illustrated by the example shown in Fig. 1.



**Figure 1.** Conventional scheme of location of consumers ( $B_1$ ,  $B_2$ ,  $B_3$ ) and potential producers ( $A_1$ ,  $A_2$ ,  $A_3$ ) of a specific good. Source: author's own study.

Let us assume that for a company that intends to produce goods for the  $B_1$  market, the most beneficial for the profit will be the location of the plant in  $A_1$  place, because in this way the following condition can be met: minimum sum of the costs of production of goods in the demand of market  $B_1$  and the costs of transport of the goods from  $A_1$  to  $B_1$ . However, it may turn out that the production of this good for the needs of not only the  $B_1$  but also  $B_2$  and  $B_3$  markets will be beneficial in the  $A_2$  location as well.

In other words, the  $A_2$  location meets the condition of the minimum sum of the costs of production of a good in the total consumer demand  $B_1$ ,  $B_2$  and  $B_3$  and the costs of transporting it in appropriate quantities from  $A_2$  to  $B_1$ ,  $B_2$  and  $B_3$ . As a result, it may turn out that the price of a good produced in  $A_2$  will be lower in  $B_1$  than the price of the same good produced in  $A_1$  (e.g. because of the benefits brought by a larger scale of production). In these circumstances, it seems wrong to decide to locate production in  $A_1$  place for consumers only in  $B_1$ , without the

hypothetical possibility that production for consumers in  $B_1$ ,  $B_2$  and  $B_3$  could be located in  $A_1$  place, thereby making production in  $A_1$  unprofitable. However, it would be appropriate to consider the decision to produce in  $A_2$  instead of  $A_1$ , but for a larger group of consumers (in  $B_1$ ,  $B_2$  and  $B_3$ ).

It is not excluded, however, that the decision to locate production in  $A_2$  place would also be erroneous, because it may turn out that in  $B_2$  place the cheapest will be the good of  $A_3$  producer, for whom the location was chosen according to the criterion of the minimum sum of production costs of the good in the demand of  $B_2$  consumer and the costs of transport from place  $A_3$  to place  $B_2$ . The producer  $A_2$ , after losing the consumer market  $B_2$  will be forced to reduce the volume of its production, which will result in an increase in unit costs and possible financial losses. The producer  $A_3$  also does not have a full guarantee of the correctness of its location.

This example shows that it is not possible, solely from the viewpoint of a separate producer (without taking into account already existing and potential producers of identical goods), to solve the task of justifying the choice of the correct location of production. That is why we are saying that, when justifying the choice of the right location for production, an industry approach is needed, i.e. one that includes a group of producers of an identical good. This makes it necessary to analyze simultaneously (and not in series!) all places of existing and possible location of production of the considered good.

Below we will discuss the next steps of each of the two stages of the above-mentioned procedure of selecting the optimal system of production technology of the considered good.

### **3. Development of the list of possible production sites (PPS)**

The establishment of the list of PPSs (stage 1 step 2) should be based on a criterion that would allow a site to be considered as PPS only if its characteristics meet those requirements of the "production of goods" side, which should or must be taken into account when justifying the choice of production site. In general, the characteristics of the "production of goods" side are the overall characteristics concerning: technology of production of goods; resources necessary for the production of goods; pollution that arises in the production of goods; goods produced. Of all the properties of the "production of goods" side, some are location factors, and they will be decisive when determining which places we are looking for for production location. Each of these selected properties of the "production of goods" side will correspond to the "place" side properties, which thus also become location factors. Therefore, when answering the question of 'where' or 'why here', we must take into account the interdependent location factors of both sides – the 'production of goods' and the 'place'.

When preparing the list of PPSs, it should be remembered that the production of the same good can be carried out with the use of different technologies, and thus with different properties

determining the location factors. As an example, in Table 1 we present a description of selected factors conditioned by the electricity generation technology used, and factors determining the selection and importance of the properties of location sites taken into account when creating the list of PPSs. It is worth noting that even with the same source of energy, we can deal with different technologies of using it to produce electricity.

**Table 1.**

*Description of the characteristics of the locations of power plants*

Type of power plant	Description of factors conditioned by the technology used to produce electricity
Coal-fired power plant	The use of coal combustion process makes the location of production strongly conditioned by the proximity of the place of extraction of this raw material, because transmission of electricity to customers is associated with lower costs than the costs of transporting an appropriate amount of coal to the place of production. Another important condition for the location of such a power plant is the proximity of sufficient water sources. The ecological factor is also important, as the technology is associated with the emission of a large amount of environmental pollution.
Solar power plant	The use of solar energy requires the location of production in a place with a potentially high solar radiation flux above a certain threshold value. A characteristic feature of solar energy facilities is the need to use large areas of location, which can no longer be used for other purposes. Solar power plants are characterized by low water demand, and, therefore, there is no requirement to locate them close to water sources.
Gas-fired power plant	The use of natural gas has the effect that the location of production depends on the proximity of sales markets, since in this case the transport of the raw material (gas) is relatively inexpensive. The technology based on the natural gas combustion process is characterized by low rates of undesirable products that may pollute the environment.
Hydroelectric power plant, run-of-river	In this case, the location of production of electricity is oriented towards locations with a high potential for energy stored in natural or artificial water dams. Efficiency of production in run-of-river power plants is associated with a year-round guarantee of access to energy from the water stream and a landscape conducive to hydro-engineering.
Hydroelectric power plant, tidal	The location of such a power plant requires a place (sea or ocean shore) where there are significant daily changes in the level of water accumulated during tides. The average tide height is about 0.5 m, except for those few places where water masses accumulate significantly, when the wave height can be 10÷20 times higher than the average value. The most advantageous locations will be those seashore plots where, in addition to the large amplitude of the tides, the shape of the shore allows for the construction of large closed basins. Tidal energy on Earth is estimated at 3 TWh per year, but only about 100 sites meet these requirements.
Nuclear power plant	The location of a nuclear power plant may be oriented towards minimizing the distance to energy consumers, as such a power plant needs several wagons of nuclear fuel per year. The condition, however, is that there are no seismic hazards in the given territory and that there is access to sources of significant amounts of water. However, the dominant factor may be the safety factor that determines the location of a nuclear power plant far from large concentrations of people.
Wind power plant	The main elements of the natural environment that affect the efficiency of a wind power plant and must be taken into account in its location are the occurrence of winds and the type of plot of land. The use of wind energy in such a power plant becomes effective only when its speed at the surface of the Earth exceeds 20 km/h. A feature of the plot favorable to the location of a wind power plant is the lack of forests and buildings. What is important is the roughness (resistance), orography (type and scale of undulating area), as well as the cohesiveness of the development of the surrounding area.
Geothermal power plant	The production of electricity in geothermal power plants requires them to be located in places that guarantee access to large geothermal water resources. A prerequisite for this is that the geothermal waters have a temperature above 140°C and a depth of occurrence of less than 5 km.

Source: author's own study.

The above example shows that for the same good (electricity), the location factors of its production will be different for different technologies used for the production. This confirms the possibility that the same good, produced based on different technologies, will be assigned to different classification groups from the point of view of its production location factors. When developing the list of PPS it should be noted that the importance of location factors is changing due to changes in technologies, market situation and state regulation of the economy.

For each PPS, a list of possible production technologies for a specific good (stage 1 step 3) is prepared, within which the optimal production technology is selected (stage 1 step 4). The basis for selecting the optimal technology is the maximum Net Present Value (NPV) index. The choice of optimal technology is a very important element of stage 1, however, this article will not elaborate on this topic further, as many scientific publications contain results of very extensive and in-depth research in this area.

#### 4. Distance competition of technologies

Comparing optimal technologies selected for specific PPSs (stage 1 step 5) can be called a distance competition of technologies, and below we will try to briefly describe the way in which this comparison is made. To this end, let us consider the situation where each of the two distant sites A and B can be used to locate the production of the same good, using the optimal technologies assigned to those sites in the previous step (step 4, stage 1).

Let us assume that the production of this good, located in sites A and B, the distance between which is equal to  $R$ , will be possible with fixed unit production costs for the assumed production scale, amounting to  $C_a$  and  $C_b$ , respectively. Let the cost of transporting a unit of goods from A to B calculated per kilometer be  $S$ . If the unit cost of production in site B is higher than the cost of production of the same good in site A, it will not yet be possible to claim on the basis of this that is not worth to produce this good in site B. In site B it will not be worth to produce the considered good only if the production of this good in site A and transporting it from site A to site B is associated with a lower total cost than the production of this good in site B. Therefore, site B will not be considered as a place where it is worthwhile to produce the considered good if the following condition is met:

$$C_a + R \cdot S \leq C_b \quad (1)$$

All PPSs are assessed against this criterion and then those technologies that did not lose the competition will be considered as prospective (stage 1 step 6).

When assessing the prospective PPSs according to the size of the market criterion (stage 2), it may turn out that it will not be profitable to produce the considered good in the place considered in stage 1 as prospective, due to the small demand in the available market zone.

Therefore, we will briefly discuss the algorithm underlying the method of shaping market zones (stage 2 step 1), because it is important not only from the point of view of the profitability of the production of goods in the assessed location, but also from the point of view of the scale of production in this place.

For this purpose, let us consider two places A and B, which were considered prospective at stage 1, and for which unit values of production costs  $C_a$ ,  $C_b$  are established. Let us assume that for both producers (A and B) the cost of transporting a unit of goods calculated per kilometer is the same and amounts to  $S$ , which is a simplification. It is then possible to find places (points) for which the difference in the cost of transporting to them the goods produced in places A and B compensates for the difference in the cost of production of these goods in A and B. A set of these points will form a line (contour-line) which separates the consumption areas of the goods of producers A and B, i.e. the areas where the total cost of production and transport is more advantageous for one of the two producers. The contour-line can, therefore, be determined by the following condition:

$$C_a + R_a \cdot S = C_b + R_b \cdot S, \quad (2)$$

where  $R_a$ ,  $R_b$  stand for distances of a specific point on the contour-line from places A and B, respectively.

The equation (2) shows that for each point on the contour-line, the difference in distance between this point and places A and B is a constant value and is determined by an equation:

$$R_a - R_b = (C_b - C_a)/S \quad (3)$$

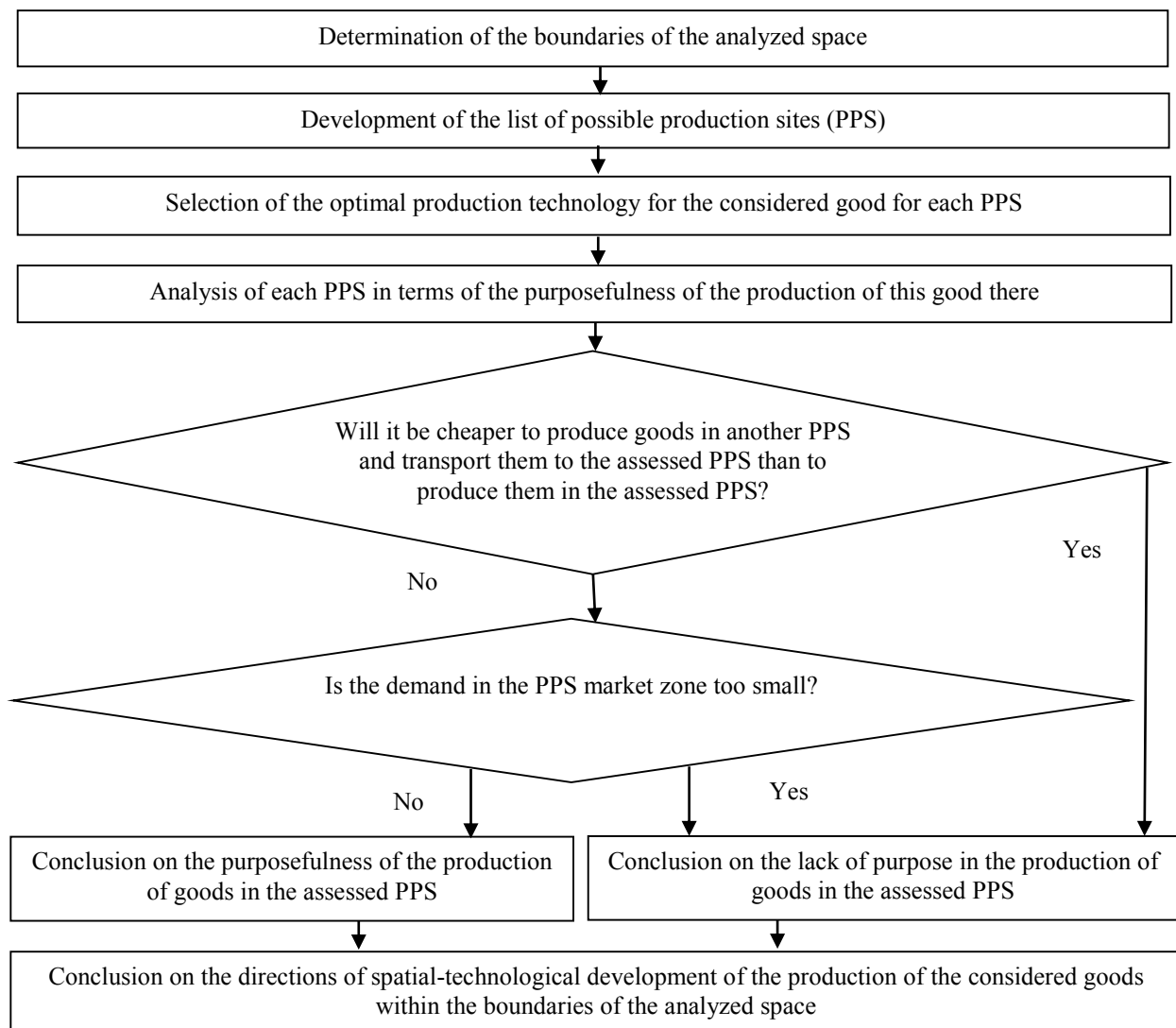
If the condition of equation (2) is fulfilled, the contour-line delimiting the predefined consumption areas for producers A and B is the hyperbola branch on the side of the place with higher production costs. According to equation (3), the location and shape of the contour-line are determined by the relative location of producers A and B, the difference in their unit production costs and the value of unit transport costs. In the case  $C_a > C_b$  the contour-line is on the side closer to producer A, and in the case  $C_a < C_b$  - it is on the side of producer B, and in the case of an equal cost,  $C_a = C_b$  - the contour-line will be perpendicular to the section connecting places A and B and passing through its center.

Consumers located on the left side of the contour-line will source from producer A as this producer will be able to offer a lower price for the goods compared to producer B due to the lower total cost of production and transport. For the same reason, consumers who are to the right of the contour-line will benefit from the price of the good provided by producer B, while consumers who are on the contour-line will be able to source from both producers at a comparable or identical price. The consumption area determination algorithm described above, applied to all prospective PPSs, is the basis for the method of establishing the final boundaries of the market zones of individual producers among these PPSs.

In determining the planned production capacity, new producers will rely on a calculation related to the total consumer demand in their market zone (stage 2 of step 2), whereas for existing producers, production capacity may vary from the value determining the profitability point of operation of the plant to the nominal value for that plant, but also based on a calculation of the total demand in their market zone. Since the above mentioned calculations will be based on the forecast market situation, when determining the maximum production capacity of the plant, the volatility of this situation, whose fluctuations may reach 10%÷15% of the forecast value, should be taken into account.

The final task in stage 2 (stage 2 step 3) will be to establish, according to the criteria based on market size, in which among the prospective PPSs production may be targeted, and consequently to establish target production sites (TPS).

The described procedure (stage 1 and 2) for the selection of the optimal system of the production technology of goods within the limits of adequately determined space is presented schematically in Fig. 2.



**Figure 2.** Schematic diagram of the optimization process of the spatial production technology system for goods. Source: author's own study.



## Conclusions

To sum up, it can be said that when justifying the choice of an optimal system of production technology of goods within the limits of the analyzed space, the following should be done:

- Provide answers to the question of "how to produce" the considered good in each PPS, with a justification based on a thorough analysis of the problem, i.e. choose the optimal technology for each PPS;
- Answer the question of "whether to produce" the considered good in a specific PPS, is justified on the basis of a detailed analysis of the issue, i.e. to indicate the TPS.

Establishing "how to produce" the considered good in each PPS (i.e. select the optimal technology for each PPS) will only be theoretical, while the practical actions will only concern those PPSs that will eventually be selected as TPSs. It is, therefore, the case that the choice of optimal, target production sites (TPS) will at the same time be the choice of optimal technologies.

In our opinion, only the way of proceeding that we presented in the article guarantees proper justification for the choice of optimal technology systems, and it is precisely this that enriches the theory of capital effectiveness with the achievements of spatial management theory. It may be interesting to see future studies on analysis of optimal production technologies that take into account the significant and not negligible connection between production technology and its location, and that will be based on the recognition of location as another component of technology resources.

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