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# Historical overview of the selection indices applied in pig breeding

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***ABSTRACT*** - Authors summarized the different selective animal breeding methods used in the pig breeding sector in the last few decades. Advantages and disadvantages of the conventional selection index procedures were summarized. The superiority of BLUP breeding values over the mass selection procedure was clarified. The economic aspects of the different traits were also examined and the most up to date economic BLUP indices were introduced as well.

***Keywords:*** pig, selection index, blup, economic methodology

## INTRODUCTION

Selective animal breeding is the artificial process where specific traits are improved by choosing superior males and females in order to create offspring generation (*Oldenbroek and Waaij, 2014*). Different methods of selection have been used in the pig industry throughout the history. The general methods of selection are: random selection, tandem selection, independent culling levels, total score method (index selection), selection index, estimated breeding value (EBV), expected progeny difference (EPD), best linear unbiased prediction (BLUP). Selection based on a selection index is the most commonly used method in genetic improvement programs for pigs (*Stas, 2017*). In pig industry measuring the important traits are accomplished through two types of performance tests which are station test and field test, respectively (*Csató et al., 2002*). Station test is more precise and accurate but currently field test have been becoming more and more frequent. The advantage of such an assessment, compared with the use of stations test, is that the assessment is a significantly cheaper. After collecting all required information measurements of different traits are combined to one score called selection index. Thus breeders can perform selection simultaneously for several traits. Structure and form of indices can differ among countries (*McPhee, 1981; Morris et al., 1982; Visser, 2004; Nagy et al., 2008; Csató et al., 2002*) based on the varying interest in the breeding objective.

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## Conventional Selection index

Index selection is a method where values of all traits of the selection criteria are combined into a single index value (*Sangsuriya et al., 2002*). Throughout many generations and centuries selective breeding of domestic animals and plants were based on the phenotypic evaluation of the individuals. Smith introduced the so called index selection in 1936 (*Kang, 2002*). The index is a numerical expression of the genetic merit of a plant or animal for its further use as a parent for the production of a new generation. Smith presented an index of the form:

$$I = b_1x_1 + b_2x_2 + \dots b_mx_m$$

Where I is an index of merit of an individual and $b_1 \dots b_m$ are weights assigned to phenotypic trait measurements represented as $x_1 \dots x_m$.. The selection index was first used for selection among inbred lines of a self-pollinated plant species (*Kang, 2002*).

Jay L. Lush who is known as the father of modern animal breeding published his work in the book called 'Animal Breeding Plans' in 1937, in this book he advocated that instead of subjective appearance, animal breeding should be based on a combination of quantitative statistics and genetic information. By this publication he greatly influenced animal breeding around the world scientists, one of them was Hazel (*Robinson, 1991*). In 1943 Hazel adapted methods originally used in plant production (*Graser et al., 2006*).

The main problem of Hazel with constructing an index was how to combine information in an optimal way on different individuals **Y** into a single number I on which selection can be based. Hazel chosen a linear approach (*Weaber, 2005*):

$$I=b' (y-\hat{y})$$

Where b' is a column vector of weightings which need to be calculated and y a row vector of observations. Note that in this very general form the vector y can include single observations on one trait from different animals, or single observations on different traits of one or more animals, as well as means of groups, e.g. mean of all progeny (*Weaber, 2005*). The Hazel selection index (*De Vries, 1989*) defines economic merit as:

$$H_i = a_1 BV_{i1} + a_2 BV_{i2} + \dots + a_n BV_{in}$$

*where,*

$H_i$ = the aggregate economic merit of an animal, i, as a parent,

$a_j$ = the relative economic weight of trait j, j = 1…n, where n = the total number of traits
$BV_{ij}$ = the breeding value of animal i for trait j.

During last 80 years since it has been introduced the theory of index selection has been improved. In general, before constructing a selection index, its purpose needs to be determined. The next step is to identify the traits involved in the breeding goal, then economic importance of every trait has to be calculated. The problem with conventional selection index is that unless the phenotypic measurements are pre-corrected by the influential environmental factors, these factors can highly modify the results. Unfortunately apart from conventional selection of body weight indices do not use data correction (Csató et al., 2002). Besides, conventional index methodology is based on the phenotype rather than the genetic merit of the animals in the different traits.

## BLUP METHODOLOGY

Best Linear Unbiased Prediction, or BLUP, is a technique for estimating genetic merits. In general, it is a method of estimating random effects. This is a method of selection and genetic evaluation of animals. It was created and development by scientist Henderson in the 1950s but because of complexity of mathematical calculations and the computer power was too limited to be able to calculate the breeding values using the animal model, the practical implementation thus had to wait until the later 1980's. As we mentioned previously the so called estimated breeding value was developed also by Henderson, it has given possibilities to breeders to rank the animals according to their estimated genetic potential, which resulted in more accurate selection results and thus a faster genetic improvement through generations (*Robinson, 1991*).

The Estimated Breeding Value (EBV) provides an estimate of the genetic potential of the animal which is expressed relative to the population average. The true breeding value (TBV) is the real value of the animal for breeding. The perfect EBV would be equal the TBV. The EBV provides the BEST estimate of the breeding value of an animal. The accuracy indicates the risk of a difference between EBV and TBV, where the TBV may be higher or lower with equal probability (*Oldenbroek and van der Waaij, 2014*). The correlation between the true breeding value and the predicted breeding value is maximized and estimates realized values for a random variable using unbiased statistical methods. (*Stas, 2017*).

If we compare effectiveness of both methods in practice based on done research, it is possible to make a conclusion that BLUP methodology more appropriate than conventional selection index based exclusively on phenotype. Response would be greater from selection using BLUP than from selection using conventional index (*Keele et al., 1988*). The BLUP evaluation officially was introduced in Hungary in 2007 and quickly replaced the conventional indices, and pig breeding companies conducting breeding also started to pay more attention to progeny tests based on slaughter-house data than they had done previously (*Houška et al., 2010*). In literature review of thesis work of *Stas (2017)* was reviewed experiment of comparison selection based on phenotype performance (conventional index) with selection based on best linear unbiased prediction (BLUP) of breeding value selection for one trait of interest at varying levels of heritability. Genetic improvement was greater for BLUP selection compared to conventional index selection; but, with increasing of heritability, the difference between the two methods decreased. Selection based on BLUP had a relative advantage compared to conventional selection index by 55% for traits of low heritability and by 10% for traits of moderate heritability. The level of inbreeding increased faster with selection based on BLUP. Nevertheless, selection based on BLUP will help to improve selection accuracy and efficiency (*Stas, 2017*).

BLUP advantages are as follows (*Csató et al., 2002*):

- the most accurate division of criteria that determine the productivity of the animal: the impact of the environment; genetics (heredity)
- the possibility of simultaneous comparison of parameters that were obtained in different environmental conditions from different genotypes, as well as from animals of different generations;
- mathematically accurate records of all documented family ties
- Adjustment of all values of breeding value in relation to each other (for example accounting for genetic competition and the level of mating)
- very high accuracy of tribal assessment, which allows achieving high selection efficiency
- More accurate prediction of breeding values through the use of information on all the relationships
- More accurate comparison of animals at different times or under different management systems by correcting environmental factors
- More direct comparison among animals by using different levels of relevant information and/or by allowing comparisons across different generations

However, it is also necessary to mention also the limits of using BLUP in the Hungarian pig sector. There is no doubt that BLUP simultaneously corrects the phenotypes for systematic effects, and it estimates breeding values while making use of the additive genetic relationships between the animals with the help of matrix algebra. But there is a critical issue in correcting for systematic effects. It only works well if genotypes are sufficiently spread across systematic environmental influences (*Oldenbroek and van der Waaij, 2014*). That is not the case in Hungarian pig breeding sector yet. There are no sufficient genetic links between Hungarian breeding farms, because of the lack of AI with the semen of the same sires used in many farms, and because breeding animals are rarely brought to various breeding farm locations, they are mainly sold to commercial farms. So the lack of exchange of animals between farms results in poor genetic links between farms and often it is not possible to estimate systematic farm effects accurately.

As mentioned previously one of the main goal which is possible to achieve by BLUP is to quantify and eliminate the influence of the environmental factors. Because different genotype in different environment can give different feedback of productivity, this is called genotype environment interaction. In different literature sources different classifications of genotype x environment interaction exist. For example *Merks (1986)* defined as a change in relative performance of two or more genotypes measured in two or more environments. James (2009) classified interactions as being either of rank-type or of scale-type. He defined rank-type interactions as those in which genotype 1 may be superior over genotype 2 in the first environment, however, the reverse may be true when tested in the second environment. *Merks (1986)* made a similar classification for rank-type interactions. In addition to the rank-type classification, *James (2009)* defined scale-type interactions as those in which the differences between genotypes change in magnitude, but not in sign, with changes in environment. The implications of these interactions have to be considered when developing a breeding program. Although the magnitude of the performance differences may change with a scale-type interaction, the ranking of the genotypes for performance will stay the same; however, with rank-type interactions, the ranking of the genotypes for performance will change with a change in environment. Therefore, rank-type interactions are potentially of more practical importance.

## ECONOMIC METHODOLOGY

After choosing all of appropriate traits and performing the procedures related to construction of selection index, breeders meet yet another problem of the economic value that will be more beneficial for certain traits compared to other traits. For this purposes were created the so called economic weights. However, when constructing an index based on economic values, only one of the traits may be included in the index in order to avoid double counting and recovering one by another for example such traits as lean meat content and back fat thickness (*Houška et al., 2010*).

Different approaches are available for construction and calculation economic weights, it depends on many factors. First citation that we found in literature describing methodology of calculating economic weights dates back to 1966. Authors Moav and Moav proposing idea about using profit equations to integrate the cost and returns of a production system to compare the profitability of lines and crosses. Main idea was that equations could be non-linear and outcome then depends on the levels of performance for the different traits. In 1973 Moav used the profit equation, and the economic weights derived from the interests on national level or producers (*Brascamp et al., 1985., Moav and Moav, 1966*)

The economic value of an individual in animal husbandry is expressed by the profit. Breeder is a main person who makes strategy of development of future selection programs; usually such activity is carried out in four stages:

- monitoring of production conditions and situation in the product market;
- analysis of profit and production costs;
- definition of important features;
- calculation of economic weight coefficients.

Main task of breeders to decide on and choose from numerous traits based on their economic importance, which means trait or traits must be improved in accordance with the objective of market demand. Selection always concentrates on improving specific traits of animals, in our case pigs, to increase specific productivity of interest and together with this increase financial welfare of industry. In general, a selection index as a function of the predicted breeding values of economically relevant traits and marginal economic values is used for example in such countries like Czech Republic and Hungary. The marginal economic values of the traits are calculated as change in predicted profit, holding all other traits constant. As mentioned previously, by reviewing literature, it is possible to make a conclusion that huge differences can be observed between countries, but also between different farms with different environment. Also can be observed a small effect of specific selection methods on reduction in production costs in different markets. Therefore, diversity in genetic lines of pigs is not directly needed, just need adaptation of lines to specific environments or farming system. This finding is in accordance with *Hanenberg et al. (2010), Stewart and Neal S.M (1999).*

Pig breeding programs generally focusing on improving traits that are responsible for production and reproduction because they are more clear and important. Of course they are short – term goals because always need to be focusing on market and customer demand and predicting future needs on time. But recently animal associations start to pay attention not only to economic importance but also to animal welfare (*Kanis et al., 2005*).

Breeders generally applying two approaches for calculating economic weights for pig breeding based on the models of *De Vries (1989)* or *Stewart et al. (1990)*. The first approach applies to an integrated commercial production system buying their female replacements from the superior production tier. The second approach relates to a commercial sow herd producing their own replacement gilts and selling weaned piglets to the growing–finishing enterprise (*Houška et al., 2004*).

On reviewing of two countries Hungary and Czech Republic we will show some examples of approaches to calculating marginal economic values, economic weights and traits that are used for these purposes.

In Hungary first estimation of economic values and marginal economic values for traits was done in 2010. In table number 1 we can see the final result of the calculation for specific traits.

Basis of constant number of sows was used for the calculation of economic values for Hungary and therefore expressions of economic values were done per sow per year. Model describing by *De Vries (1989)* was used as approaches for calculating. Based on the data we can observe that best marginal economic values were the number of piglets born alive but based on standardized economic values the percentage of valuable cuts in the carcass was most economically important trait (*Houška et al., 2010*).

As authors mentioned in their conclusion for calculating economic weight we just simply need multiplied breeding values by the marginal economic values and we can build economic selection index (*Houška et al., 2010*).

In the research of *Houska et al. (2004)* it was showed that the production system in Czech Republic is similar to the Hungarian and therefore the model of *De Vries (1989)* was used for calculating. Marginal economic value and economic value were also calculated. But for calculating economic weights the so called discounted expressions which were multiplied by marginal economic values were used. The discounted gene flow is expressed as a number of cumulative discounted expressions (CDE), as a consequence of one mating; "cumulative" refers to an accumulation of expressions over generations or years; and "discounted" implies to the fact that future return is discounted to today's values by a discounting factor (*Jiang et al., 1999*).

**Table 1**
Marginal economic values (MEW, in EUR per unit of trait, per sow and year when improving the trait level), genetic standard deviation (GSD), standardized economic values (SEW, in EUR/GSD)

| Trait (unit) | MEW | GSD | SEW |
|---|---|---|---|
| Number of piglets born alive (piglets) | 54.22 | 0.61 | 33.07 |
| Age at slaughter (days) | 2.71 | 15.02 | 40.70 |
| Days in fattening | 2.84 | 9.91 | 28.14 |
| Lean meat content in the carcass (%) | 22.45 | 1.62 | 36.37 |
| Percentage of valuable cuts in carcass (%) | 28.81 | 2.55 | 73.46 |

## CONCLUSION

Conventional selection index resulted huge benefit in past, animals were selected based on phenotypic variation. However after some period of time when the methodology reached its maximum potential new procedures became widespread.

Best Linear Unbiased Prediction (BLUP) is a method that substitutes conventional phenotypic measurements in the selection index. It is more precise and accurate in prediction genetic potential of animals, taking into consideration the relationships among the animal and the influencing environmental factors. BLUP allows comparing animals merit within different farm with different environment, which is impossible to do with conventional methods.

Economic methodology in constructing selection index is the method by which we evaluate the economic value of each trait and get so called economic weights. This coefficient can be used to calculate aggregated breeding value thus profit can be maximized in the procedure of selection.

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## REFERENCES

Brascamp E.W., Smith C., and Guy D.R., 1985. Derivation of economic weights from profit equations. Anim. Sci., *40*(1), 175-179. DOI: *10.1017/s0003356100031986*

Cameron N.D., 1997. Selection indices and prediction of genetic merit in animal breeding. CAB international. URL: *Link*

Csató L., Nagy I., Farkas J., and Radnóczi L., 2002. Genetic parameters of production traits of Hungarian Pig populations evaluated in separate and joint (field and station) tests. Archives Ani. Breed., *45*(4), 375-386. DOI*: 10.5194/aab-45-375-2002*

De Vries A.G., 1989. A model to estimate economic values of traits in pig breeding. Lives. Prod. Sci., *21*(1), 49-66. DOI: *10.1016/0301-6226(89)90020-1*

Graser H., James I., and Van der Werf I., 2006. Optimal designs of breeding programs.

Hanenberg E., Mathur P.K., and Knol E.F., 2010. Marginal economic values for pig production in different countries. In 9th World congress on genetics applied to livestock production Leipzig, Germany.

Houška L., Wolfová M., and Fiedler J., 2004. Economic weights for production and reproduction traits of pigs in the Czech Republic. Lives. Prod. Sci., 85(2-3), 209-221. DOI: *10.1016/s0301-6226(03)00128-3*

Houška L., Wolfová M., Nagy I., Csörnyei Z., and Komlósi I., 2010. Economic values for traits of pigs in Hungary. Czech Journal of Ani. Sci., *55*(4), 139-148. DOI: *10.17221/100/2009-cjas*

James J.W., 2009. Genotype by environment interaction in farm animals. In Adaptation and Fitness in Animal Populations (pp. 151-167). Springer, Dordrecht. DOI: *10.1007/978-1-4020-9005-9_10*

Jiang X., Groen A.F., and Brascamp E.W., 1999. Discounted expressions of traits in broiler breeding programs. Poul. Sci., 78(3), 307-316. DOI: *10.1093/ps/78.3.307*

Kang M.S., (Ed.)., 2002. Quantitative genetics, genomics, and plant breeding. CABI.

Kanis E., De Greef K.H., Hiemstra A., and Van Arendonk J.A.M., 2005. Breeding for societally important traits in pigs. Journal of Ani. Sci., *83*(4), 948-957. DOI: *10.2527/2005.834948x*

Keele J.W., Johnson R.K., Young L.D., and Socha T.E., 1988. Comparison of Methods of Predicting Breeding Values of Swine 1, 2. Journal of Ani. Sci., 66(12), 3040-3048. DOI: *10.2527/jas1988.66123040x*

McPhee C.P. 1981. Selection for efficient lean growth in a pig herd. Australian Journal of Agr. Res., 32(4), 681-690. DOI: *10.1071/ar9810681*

Merks J.W.M., 1986. Genotype and environment interactions in pig breeding programmes. I. Central test. Live. Prod. Science, *14*(4), 365-381. DOI: *10.1016/0301-6226(86)90015-1*

Moav R., and Moav J., 1966. Profit in a broiler enterprise as a function of egg production of parent stocks and growth rate of their progeny. British Poul. Sci., *7*(1), 5-15. DOI: *10.1080/00071666608415600*

Morris C.A., Goss B.M., and Wolskel R.H. 1982. Offspring-sire regressions for production traits of pigs in a West Australian selection herd. Australian Journal of Expe. Agric., *22*(115), 47-53. DOI: 10.1071/ea9820047

Nagy I., Csato L., Farkas J., Gyovai P., Radnoczi L., and Komlosi, I., 2008. Genetic parameters of direct and ratio traits from field and station tests of pigs. Archives Ani. Breed., *51*(2), 172-178. DOI: *10.5194/aab-51-172-2008*

Oldenbroek K., and van der Waaij L., 2014. Textbook animal breeding: animal breeding and genetics for BSc students. Centre for Genetic Resources and Animal Breeding and Genomics Group, Wageningen University and Research Centre.

Robinson G.K., 1991. That BLUP is a good thing: the estimation of random effects. Stat. Sci., 15-32. DOI: *10.1214/ss/1177011933*

Sangsuriya P., Reodecha C., and Chavananikul V., 2002. Selection Index for Reproductive Traits in Purebred Swine.

Schüler L., Swalve H., and Götz K.U., 2001. Grundlagen der quantitativen Genetik*: 94 Tabellen*. Ulmer.

Stas N.M., 2017. Effect of sire line and selection index category on pig growth performance from weaning to harvest and carcass characterisitics (Doctoral dissertation).

Stewart T.S., and Neal S.M., 1999. Multiple trait selection for pork improvement. NSIF-FS10. URL: *Link*

Stewart T.S., Bache D.H., Harris D.L., Einstein M.E., Lofgren D.L., and Schinckel A.P., 1990. A bioeconomic profit function for swine production: application to developing optimal multitrait selection indexes 1. Journal of Ani. Breed. and Gen., 107(1-6), 340-350. DOI: *10.1111/j.1439-0388.1990.tb00043.x*

Visser D.P., 2004. Structuring of breeding objectives in the pork supply chain in South Africa (Doctoral dissertation, University of Pretoria). URL: *Link*

Weaber R.L.B., 2005. Introduction to Indexes. 37$^{th}$ BIF Annual Research Symposium and Meeting.