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CHAPTER 15

Case studies, calculation examples

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15.1 The role of quality and logistics costs in sugar beet procurement (Magyar Cukor Zrt.)

The case study was based on the study of the same title by Horváth, Csonka, Szerb, Csima[1] and presents the raw material supply system of Magyar Cukor Zrt.

15.1.1 The role of quality and logistics costs in sugar beet procurement

Magyar Cukor Zrt.'s sugar beet procurement process system is implemented through five phases from the conclusion of the contract. The campaign-like implementation of these phases is regulated by agreements between the producer association and the sugar factory, based on standards and well-established routines. As a result, in this study we deal less with operational process management, the characteristics of each phase are briefly presented in Table 1.

Table 1. *Organization of sugar beet supply at the Kaposvár sugar factory*

Phase	Characteristics
Contract conclusion	• Rounds of negotiations (2-3) with the National Association of Sugar Beet Growers on contract terms (January) • Signing contracts with producers (February-March)
Production supervision	• documentation of operations during cultivation (obligation of the producer) • the M.C. Zrt. sampling tests and insight into the documentation • watering after August 31 only in extreme weather conditions, the M.C. With the permission of Zrt.
Harvesting and delivery	Duties of producer: • defoliation and cleaning during harvesting • storage next to the board (storage for 3-5 weeks) • providing road transport to the factory or railway loading station M.C. Zrt.'s duties • preparing a delivery schedule (negotiations 2-3 weeks before the campaign) • creation of transport groups (8-10 producers/group) • road freight reimbursement, organization of rail transport
Quantitative and qualitative handover	• acceptance based on the MSZ 17045:2002 standard • RÜPRO probe sampling, laboratory quality testing (M.C. Zrt.) • producers can send an authorized specialist to check the acceptance • protocol in the event of a sampling dispute

Financial Accounting	• The M.C. Zrt. notifies the producer within 5 days after receipt of the details of the receipt log (by mail or e-mail) • The M.C. Zrt. prepares an account within 15 days from the producer's last delivery • payment within 15 days of receipt of the producer's invoice • after the delivery of 50 percent of the contracted quota sugar beet, the producer has the opportunity to take an advance amounting to 50 percent of the expected sales revenue

In the following sub-chapters, we present some raw material supply problems – typically occurring at the tactical and strategic level – that greatly affect the effectiveness of cooperation between agricultural producers and processors in the case of the sugar factory.

15.1.2 The key figures for sugar beet procurement between 2009 and 2016

The development of the sugar beet growing area contracted by Magyar Cukor Zrt. and the quantity of sugar beet delivered is shown in 16.1. figure shows. It can be seen in the figure that during the examined period, the contracted production area was characterized by rather large fluctuations and instability, and after the 2006 sugar reform, the sugar beet market was difficult to consolidate. This fluctuation is a good indication of one of the biggest challenges of beet procurement for the sugar factory in Kaposvár: if the sugar factory wants to use its production capacity to the maximum extent, then it has relatively little scope for supplier selection. The proportion of stable agricultural producers intending to contract with the same volume year after year is relatively small, a significant part of the supply depends on how many of the producers who are less committed to sugar beet cultivation decide to grow sugar beet, given the current price and production cost conditions, and on what area. It is a telling fact that during the period, out of the 490 producers in the supplier base, only 33 delivered sugar beet to the sugar factory every year. The primary driver of the fluctuation is the price development of corn, a competitive species that can be grown at a lower cost and is technologically less demanding. As a secondary reason, the expansion of the Croatian sugar factories near the border towards Hungarian production areas can be mentioned. Many producers enter into shared contracts with both Kaposvár and Croatia processors, and territorial proportions are decided on an annual basis, depending on the purchase price, premiums and other contractual conditions.

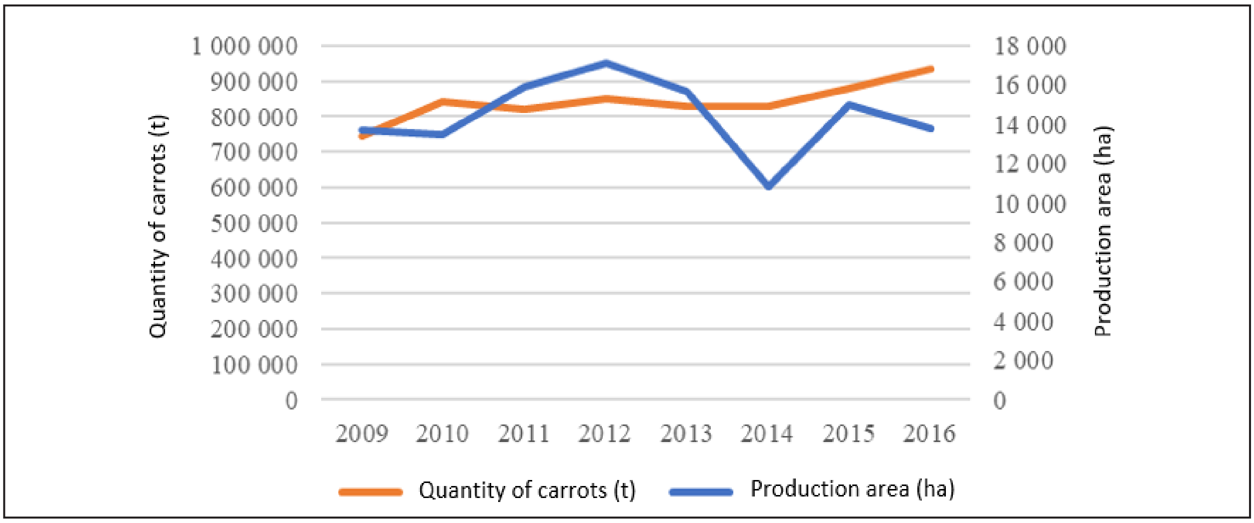

Figure 1. *The development of the contracted production area and the quantity of delivered beets at Magyar Cukor Zrt (2009–2016)*

Despite the fluctuations in the production area, the delivered beet volume was characterized by a balanced growth during the period under review. This phenomenon clearly reflects the fact that after the sugar reform, a "cleansing" process took place in the sector. The more competitive sugar beet producers who remained on the product line – in many cases in cooperation with the processor – were able to develop technology and production management, thanks to which both the average yield and the white sugar yield per hectare increased significantly (see Figure 2).

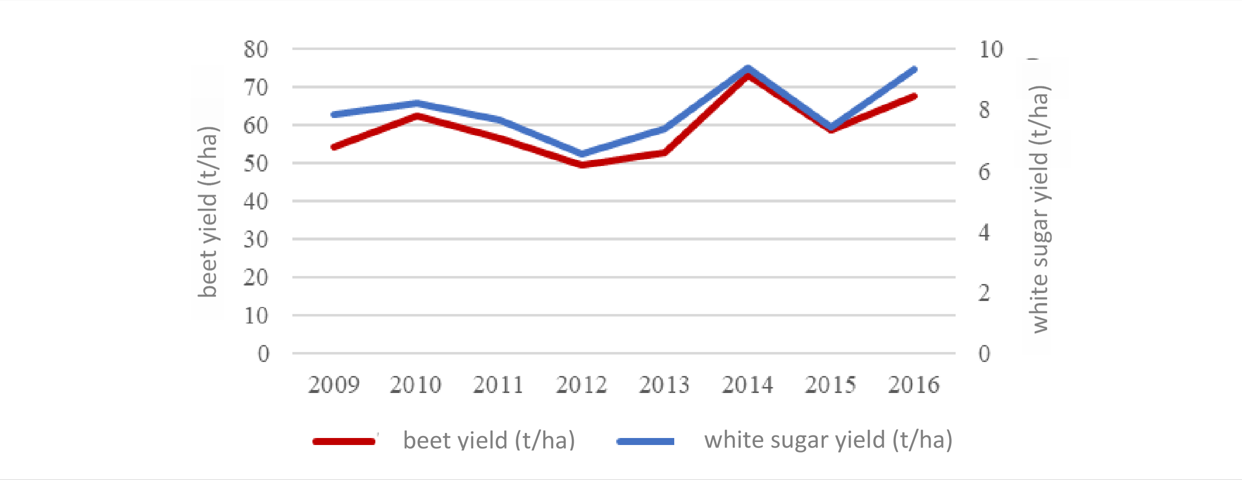

Figure 2. *Average yield and white sugar yield at Magyar Cukor Zrt (2009–2016)*

1. and 2. from the comparison of Fig. 1, it can also be concluded that the development of specific yields – in addition to the rising trend – moved in the opposite direction to the fluctuations of the cultivated area in the individual years. The dramatic increase in the cultivated area caused a decrease in the average yield, and we can also see examples of the opposite. This opposite movement ultimately resulted in the low annual volatility of the delivered beet volume. This phenomenon once again confirms that the supplier base of the Kaposvár sugar factory is characterized by duality. Side by side, there is a stable group of suppliers capable of achieving a relatively higher average yield and sugar yield, with a constant volume, and an unstable group characterized by lower productivity and large fluctuations in the area of production. The latter group carries a greater risk in terms of the security of raw material supply.

As the next element of the examination of supply trends, we present the evolution of the number of suppliers and their average production area (Figure 3).

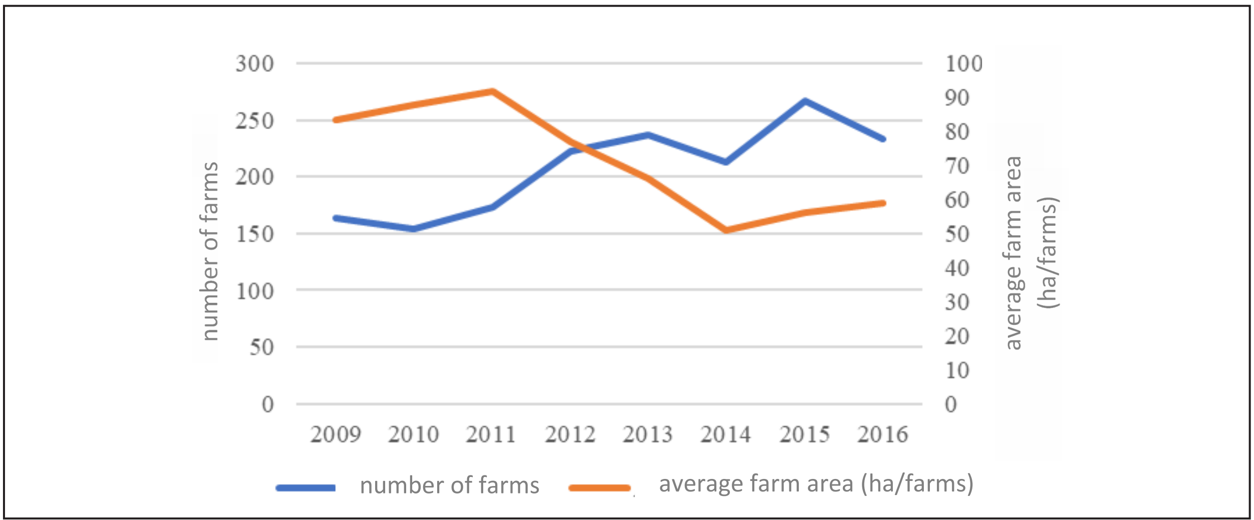

Figure 3. *Development of the number of producers and the average production area at Magyar Cukor Zrt (2009–2016)*

The figure shows that the number of suppliers increased significantly as a result of the intention to increase the supply of raw materials. At the same time, however, the average cultivated area decreased, i.e. compared to previous years, producers contracted for sugar beet cultivation on a significantly smaller area. The decrease in the average cultivated area once again provides another explanation for the fluctuation of suppliers: the smaller the area the producer farms, the less likely it is that sugar beet will be included in the crop structure in each successive year.

Our next question is how the geographical location of the producers and their distance from the sugar factory developed. Since the transport costs are mainly borne by the processor, the transport distance is of fundamental importance from the point of view of raw material supply. As we wrote earlier, only an extremely small proportion of the mass of sugar beet delivered to the sugar factory is the realizable sugar content. Thus, long-distance delivery can be said to be extremely expensive. Despite this, and due to the previously mentioned low scope for supplier selection, the average transport distance increased during the examined period (Figure 4).

Sugar beet can arrive at the sugar factory via two possible routes: either directly by road or by combined road-rail transport (via the nearest railway station suitable for loading). The figure shows that the average road haulage distance is really low, ranging between 20-26 km in most years. The rail transport distance, and with it the total transport distance, on the other hand, increased sharply between 2009 and 2012, and then stabilized above 250 km. This transport distance can be said to be particularly high in domestic terms. With such transport distances, the specific logistics cost is extremely high: in the examined years, it ranged between 7-8 euros/ton, which is 25-30 percent of the beet's basic purchase price.

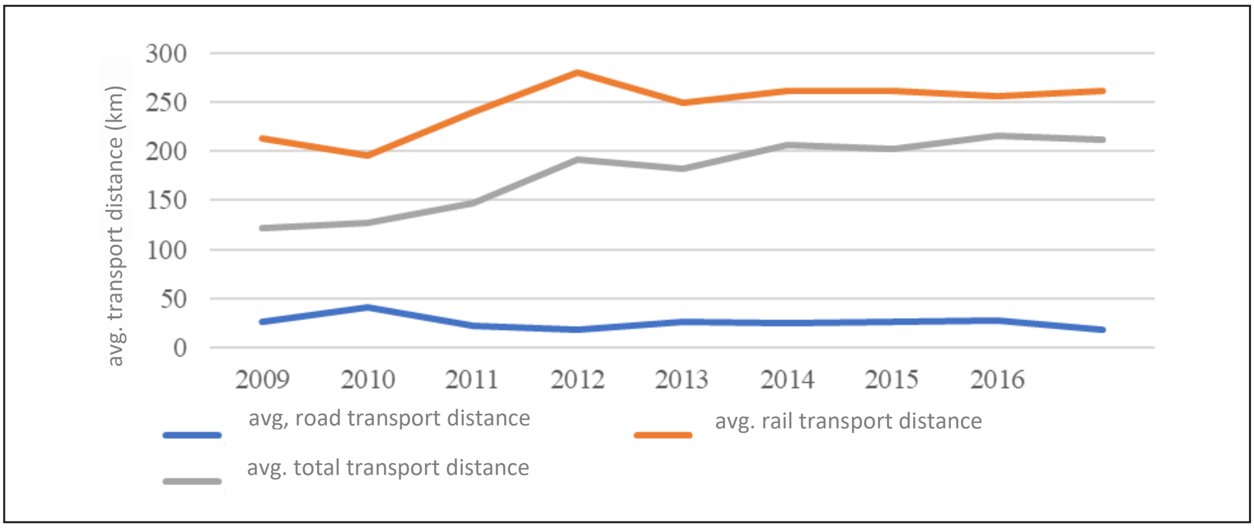

Figure 4. *Development of the average transport distance at Magyar Cukor Zrt (2009–2016)*

15.1.3 Tools to encourage the stability and quality performance of the supplier base at Magyar Cukor Zrt

One of the most important lessons from the previous sub-point is that the Kaposvár sugar factory has little opportunity to select among sugar beet producers, instead it should strive to use tools that encourage stable and permanently high quality. One of the basic ways to do this is to use premiums built into the contract.

The acceptance price of sugar beet, as well as the extent of other producer benefits above the base price, is contained in the Sugar Beet Production and Sales Contract (hereinafter: Contract) concluded annually between Magyar Cukor Zrt. and the producers. The base price established in the contract is set in euros, applies to beets with a sugar content of 16%, and essentially represented the base price set by the EU (26.29 EUR/t) during the period under review. This static price is always complemented by dynamic elements that encourage quality performance and production stability.

On March 26, 2004, the Interprofessional Agreement concluded by the Sugar Industry Association (CIE) and the CTOSZ entered into force[2]. The agreement, which has been in effect ever since with a minor amendment[3], regulates the price adjustment based on the measured sugar content, as follows:

"If the sugar content of the sugar beet at the time of acceptance differs from 16.0 %, then in the event of a change in the exact sugar content of 0.1 %, the minimum sugar beet price:

a) It should be increased:

- 0.9% for sugar content exceeding 16% but not exceeding 18%,
- 0.7% for sugar content exceeding 18% but not exceeding 19%,
- 0.5% for sugar content exceeding 19% but not exceeding 20%;

b) It should be reduced:
- 0.5% for sugar content below 16% but not lower than 15.5%,
- 1.0% for sugar content below 15.5%.

The price of beets with a sugar content greater than 20% is the same as the adjusted price applied for beets with a 20% sugar content.

The sugar factory and the regional association(s) agree separately on the acceptance of sugar beets with a sugar content of less than 14%."

As can be seen, the rate of price increase/decrease in each interval significantly exceeds the rate of increase/decrease in sugar content. This in itself indicates that the pricing system is a great motivation to achieve a higher sugar content. We can get a more accurate picture of this by using a model calculation to examine how it affects the income per hectare available to producers.

Producers can increase their available income per hectare in two ways: by maximizing the yield per hectare, and by maximizing the percentage of sugar content of the sugar beet. The effect of these two important indicators on income is demonstrated with simple model calculations (according to the basic contract of 2013)

a) The effect of the increase in the average yield at a fixed (16%) sugar content.
- In this case, the formula is very simple: every 0.1 t/ha increase in average yield increases the income per hectare (calculated with a base price of 26.29 EUR/t and a total premium of 10.71 EUR/t) by 3.7 EUR. Calculated at an exchange rate of HUF 300/euro, this corresponds to an income increase of HUF 1,110/ha.

b) The effect of an increase in sugar content with a fixed average yield
- In this case, the degree of influence of the examined variable is also influenced by the yield average and the sugar content interval. Therefore, we calculated the results for several scenarios, based on the 2008-2013 crop averages. To summarize the results, we can say the following (calculated at HUF 300/EUR exchange rate):
  i. In the case of an average yield of 49.63 t/ha (minimum of the years 2008-2013), an increase in sugar content of 0.1 percentage point results in an average increase of 3,433.05 HUF/ha (equivalent to an increase in average yield of 0.31 t/ha with a sugar content of 16%);
  ii. In the case of an average yield of 56.92 t/ha (2008-2013 average), an increase in sugar content of 0.1 percentage point results in an average increase of HUF 3,937.31/ha (equivalent to an increase in average yield of 0.35 t/ha with 16% sugar content);
  iii. In the case of an average yield of 67.79 t/ha (the maximum for the years 2008-2013), a 0.1 percentage point increase in sugar content results in an average increase of HUF 4,689.23/ha in revenue (equivalent to an increase in average yield of 0.42 t/ha with 16% sugar content).

In addition to the quality premium, producers can also receive a number of premium payments according to the contract. Among the premiums, there are permanent elements that are repeated every year (e.g.: logistics reimbursement, cleaning reimbursement, beet slice redemption fee), which continuously encourage the undertaking of the appropriate delivery schedule (e.g. compensation paid for delivery undertaken late or early in the campaign), the harvest guaranteeing adequate cleanliness the application of technology, or even the transfer of carrot slices for biogas production purposes.

Another group of premiums is included only from time to time, aimed at encouraging specific developments (technological development premium) or maintaining the circle of suppliers (loyalty premium, stabilization premium, technical development surcharge). In some years, the amount of the premiums can even reach 30 percent of the base price, so it is a tool with a significant economic impact from the point of view of both the sugar factory and the supplier.

Premiums for stabilization and technological development are primarily a means of retaining larger suppliers. In these farms, they typically think long-term about sugar beet cultivation, and have many special and expensive tools. The premiums listed here try to compensate for the costs of this long-term commitment.

In summary, it can be concluded that Magyar Cukor Zrt. incorporates a number of quality promotion tools into contracts, thanks to which a significant improvement was experienced in the average yield, average sugar content and sugar yield per hectare in the years under review.

15.1.4 Tools aimed at reducing logistics costs

The sugar factory now has far fewer tools to keep logistics costs under control. We have already mentioned the limitations related to transport distances. In addition to the given distance, reducing the logistics costs projected on the final product (white sugar yield) becomes even more important for this reason. To this end, the sugar factory stipulates in the contract the use of a suitable mechanical cleaning harvesting and stacking machine (cleaning reimbursement is a permanent premium related to this), and reserves the right to designate a sugar beet depot next to the sign.

The effect of the difference in sugar content on the cost of sugar delivery can be found in section 2. table, using the example of three transport distances.

Table 2. *Effect of the average sugar content on the value of the transport cost per white sugar mass*

Average sugar content		14,00%	15,00%	16,00%	17,00%	18,00%	19,00%	20,00%
Average white sugar yield content		12,10%	12,96%	13,82%	14,69%	15,55%	16,42%	17,28%
Distance	**Delivery method**	**Transport cost per mass of white sugar**						
25 km	Public road	5,23	4,88	4,58	4,31	4,07	3,86	3,66
90 km	Railwayery method	8,17	7,62	7,15	6,73	6,35	6,02	5,72
	Public road	15,40	14,38	13,48	12,68	11,98	11,32	10,78
236 km	Railwayery method	17,51	16,34	15,32	14,42	13,62	12,90	12,26

The table contains a model calculation that ignores the value of by-products. Thus, the nominal values included in it do not reflect the real cost content, but are suitable for estimating the relative differences. During the calculation, we used the simplifying condition that the average sugar content does not affect the specific mass of the sugar beet.

Under the above conditions, we can say that the change in sugar content results in significant differences in the transportation cost per weight of white sugar. The maximum value of the difference expressed in forints is HUF 1.57 per kilogram over a road distance of 25 kilometers, which already reaches HUF 5.25 per kilogram over a rail distance of 236 kilometers.

The two main problems of the organization of road transport are the distance on which the toll payment is based and the determination of the toll-paying mass. The latter is determined simply: the Company pays compensation for 108% of the acceptance (cleaned) mass. The producer must cover the additional costs resulting from a higher degree of pollution from his own pocket. The toll-paying distance between the table-edge depot and the sugar factory is established every year with the help of a satellite area survey, by determining the shortest route.

Another method of sugar beet transport is combined road-rail transport, which is used for road distances of over 90 kilometers. The first step of combined transport is to deliver the sugar beet to the railway loading station by road. In this case, the transport is also the responsibility of the producer, against the fee shown above. Magyar Cukor Zrt. is responsible for the cost of rail loading and transport from the loading station. The question is whether the inclusion of the railway makes the delivery of raw materials cheaper (and if so, by how much). On the example of transport from some highly important railway loading stations, the comparison is shown in table 3. can be found in the table.

It is clear from the table that rail transport is significantly cheaper over the already mentioned distance of 90 kilometers.

Table 3. *Comparison of road and rail freight charges charged to the Kaposvár sugar factory*

Loading station	Railroad distance to the sugar factory (km)	Ratio of the road cost to the rail cost for the same distance
1	236	197
2	109	143
3	263	201
4	158	184
5	234	175
6	188	150
7	94	188
8	202	178

15.1.5 Summary

In our study, we examined quality promotion and logistics cost reduction tools in the sugar beet procurement system of Magyar Cukor Zrt. Based on our results, it can be stated that the company uses the tools recommended in the international literature. The positive effect of the quality, technological and stabilization surcharges and premiums is clearly visible in the increase in the average yield and the sugar yield per hectare.

The premiums could reach up to 30 percent of the base price in the examined period, so they provide significant compensation to farmers who are committed to sugar beet cultivation in the long term, and also contribute to the implementation of further, specialized technological developments. At the same time, they did not provide enough coverage to reduce the extremely high supplier fluctuation during the period under review. The examined data suggest that the reduction of turnover and sowing area fluctuation will be achieved through increasing the size of suppliers.

However, the sugar factory has significant constraints in reducing transport distances, which account for the largest proportion of logistics costs: during the period under review, transport distances and, with it, specific logistics costs increased. This can be offset by the improvement of quality performance, as this can reduce the logistics costs for the final product.

15.2 Application of simpler decision support methods in procurement

In this case study, we can see some simple examples of the preparation of decisions aimed at the acquisition of logistics equipment.

A mineral water distributor would like to purchase electric pallet trucks for its newly built roll warehouse. The task seems simple, but two questions immediately arise:

ak) What should be the most important features (aspects) that play a role in making the decision?

al) How many alternatives should we include in our decision, and what should they be?

There are many ways to answer the questions. We can involve external experts, we can create a team of employees and managers already experienced in the subject, we can contact the various brand representatives and forklift distributors, we can find information on the Internet, we can order catalogs, etc.

For the sake of simplicity, let's assume that our experts don't want to overload us and instead collect the forklift data available from the catalogs.

For examples of forklift descriptions, see: https://www.jungheinrich.hu/fileadmin/minion/hu/tx_jhproducts_ffz/5365_hu-hu/assets/efg_110__113__115_t__puslap.pdf

15.2.1 Selection of evaluation criteria

Looking at the pdf file, we can see that the number of properties is quite large. The simultaneous inclusion of 20-30 available properties would make it difficult to use our methods. So we ask the experts to pick the six qualities that:

- *most affect* the efficiency and economy of warehouse work;
- *in addition*, they make it possible to differentiate the different types of forklifts.

The aspects are denoted by X_n, since we are not dealing here with states of fact that occur with different probabilities, but with "fixed" properties.

The six selected aspects are as follows:

- X_1: *load capacity (kg)*
- X_2: *turning radius (mm)*
- X_3: *travel speed with load (km/h)*
- X_4: *Battery operating time (Ah)*
- X_5: *net price (million HUF)*
- X_6: *reliability (failure, need for service, "durable" ability)*

In the case of the X_6, we do not have catalog data, which means that the evaluation of this aspect also awaits our well-established experts.

Since this property is not quantitative but measures quality, it was necessary to introduce a scale consisting of the following categories: weak; acceptable; average; good; excellent

15.2.2 Setting up the decision matrix

After that, there is no obstacle to rewriting the data of the original catalogs – similar to the example file – *into the decision matrix* containing our own aspects (see table 4).

The columns of the matrix represent the different aspects, and the rows of the matrix represent the *four alternatives* (that is, the four forklift types selected by the experts to be evaluated). The alternatives are denoted by S_n.

Table 4. *The decision matrix of the forklift selection task*

	X_1	X_2	X_3	X_4	X_5	X_6
S_1	2000	1550	4,5	160	1,88	Excellent
S_2	1500	1460	4,5	160	1,70	Average
S_3	2000	1595	3,6	210	1,61	Good
S_4	1500	1400	4,0	70	0,99	Acceptable

Now we have a table reflecting our own criteria, based on which we can run our procedures.

The values belonging to individual cells of the table will be denoted by xij, where the i in the index denotes the rows (alternatives), while the j denotes the columns (points of view). E.g. x14 = 160; x41 = 1500.

15.2.3 Application of elimination procedures

With this group of procedures, our goal is to reduce the number of alternatives, and not necessarily to find the only best solution. This seems less justified in the present example, since – for the sake of transparency – we only have a few alternatives. In real life, however, it happens that we have 10-20 alternatives, the number of which we would like to narrow down. The narrowing can be done on the basis of several philosophies (our starting point in all cases is table 16.4).

Satisfying (conjunctive) method

In this method, we establish an aspiration (or in other words: satisfaction) level for each aspect. The designation of the aspiration level is: $\mathbf{x^0_j}$, where j in the index corresponds to the index number of the given aspect.

In order to properly apply the aspiration level, it must be seen that in our table there are aspects for which the highest value is desirable *(aspect to be maximized)* and there are some for which the lowest value *(aspect to be minimized).*

✓ *The first group includes X_1, X_3, X_4 and X_6;*

✓ *the second group includes X_2 and X_5.*

The satisfaction level means a threshold, or the value below which (in the case of an aspect to be maximized) or above (in the case of an aspect to be minimized) we cannot accept the alternative.

Only those alternatives can remain, and those that satisfy all aspiration levels at the same time.

Mathematically stated:

S_i is acceptable if

✓ $x_{ij} \geq x^0_j$ *for all indices j, where the larger value is the better,*

✓ $x_{ij} \leq x^0_j$ *for all j indices where the smaller value is better.*

In this procedure, we get rid of all alternatives that could not fulfill even one aspiration level. A good example of this is the admission to the state examination, where the condition is that all subjects taken must be completed at least at a sufficient level.

Returning to our example, let's have our aspiration level x^0 = (1500, 1500, 4.0, 100, 1.80, avg).

Let's now compare this with the data of our decision matrix (Table 5)!

Table 5. *Elimination according to the conjunctive method*

	X_1	X_2 (min!)	X_3	X_4	X_5 (min!)	X_6
S_1	2000	~~1550~~	4,5	160	~~1,88~~	Excellent
S_2	1500	1460	4,5	160	1,70	Average
S_3	2000	~~1595~~	~~3,6~~	210	1,61	Good
S_4	1500	1400	4,0	~~70~~	0,99	~~Acceptable~~
X^0_j	**1500**	**1500**	**4,0**	**100**	**1,80**	**Average**

The values that do not meet the aspiration level have been crossed out (in the case of X_2 and X_5, the lower value is better!).

Looking at the table, we could also say that our filtering was "too good", since there was only one type of forklift (S_2) that did not have a crossed-out value in its row, i.e. that met the expected value for all aspects.

The choice of satisfaction level is of course in the hands of the decision maker, so if you want to keep more alternatives for the final decision, you can experiment with other threshold values.

Disjunctive method

We keep those alternatives *that are outstanding* in at least one of their properties. This approach can also be viable in company decisions similar to the present example.

The disjunctive procedure can therefore be given as follows:

✓ $x_{ij} \geq x^0_j$, j = 1 or j = 2 or j = m.

Be

x^0 = (2000; 1400; 4,8; 200, 1,0; excellent).

In this case, we have to cross out many more values in the matrix (see table 6).

In this procedure, the S2 alternative, which proved to be reliable in all respects in the previous point, falls out, since this truck alone did not meet any aspiration level.

Table 6. *Elimination according to the disjunctive method*

	X_1	X_2	X_3	X_4	X_5	X_6
S_1	2000	~~1550~~	~~4,5~~	~~160~~	~~1,88~~	Excellent
S_2	~~1500~~	~~1460~~	~~4,5~~	~~160~~	~~1,70~~	~~Average~~
S_3	2000	~~1595~~	~~3,6~~	210	~~1,61~~	Good
S_4	~~1500~~	1400	~~4,0~~	~~70~~	0,99	~~Acceptable~~
X^0_j	**2000**	**1400**	**4,8**	**200**	**1,0**	**Excellent**

15.2.4 Elementary decision-making procedures for finding the best solution

In the previous subsection, three methods narrowing the scope of our action options were presented. Continuing with the example we started, let's now review some of the procedures with which we strive to achieve the best solution.

Lexicographic method

The steps of the method are as follows:

a) prioritization of aspects;
b) selection of the best alternative based on the aspect deemed most important;
c) in the event of a tie in the second step (several alternatives are ranked first), the second most important aspect must also be included in the analysis;
d) in the event of a repeated tie, we continue the procedure with the next aspect, until only one alternative remains.

To test the method, we need the decision matrix again (see table 4)
Let's say the order of importance of the criteria is X_3, X_4, X_1, X_5, X_2. X_6 .

✓ The most important aspect is therefore the travel speed under maximum load, for which we have two best alternatives (S_1 and S_2).
✓ Because of the tie, we have to include the second most important aspect *(X_4)*, i.e. battery life per charge. Here - and for possible further steps - we only compare the two alternatives in the "competition". Unfortunately, we are still dealing with equality ($x_{14} = x_{24} = 160$).
✓ We must continue the comparison with the *X_1* (maximum load capacity) aspect. The relevant values are $x_{11} = 2000$ and $x_{21} = 1500$, so the question is settled: *S_1 will be the best choice.*

Repeat the process with the following order of importance: X_5, X_6, X_1, X_2, X_4, X_3.

✓ In contrast to the previous case, we can immediately select the best alternative (S_4) based on the first criterion, since we have only one best value ($x_{41} = 0.99$).

It can be seen that the value judgment of the decision-maker greatly influences the outcome and results of the decision-making procedures through the establishment of the order of importance. The same is true for determining the aspiration level of the elimination procedures in the previous lesson.

It is important to see that different "optimal" results can be obtained depending on the individual decision-making procedures and also on the preferences of the decision-makers. From among the methods, the decision-maker must choose the one that is closest to his own decision mechanism "existing in his head" and value judgment.

Data quantification and transformation

Before we move on, we need to make a *short detour* in getting to know the methods for finding the best solution. The decision matrix used so far was excellent for our purposes, however, there are some obstacles to the application of the following two procedures.

In order to identify the obstacles, let's review the list of criteria once more!
✓ X_1: load capacity (kg)
✓ X_2: turning radius (mm)
✓ X_3: travel speed with load (km/h)
✓ X_4: Battery operating time (Ah)
✓ X_5: net price (million HUF)
✓ X_6: reliability (failure, need for service, "durable" ability)

Our difficulties related to the aspects are as follows:
✓ he units of measurement are not the same
✓ quantitative and qualitative criteria are mixed
✓ they are in the opposite direction (there are also parameters to be maximized and minimized)

The previous procedures *examined the aspects* one by one, separately, so these difficulties did not cause any particular problems.

However, in order to be able to *handle the values of the table at the same time and not grouped by aspect*, our matrix must be transformed (without distorting the information contained in the original data).

Let's start with the simpler task! The decision matrix contains a quality aspect (X_6, reliability), the verbal scale of which must be quantified.

During the process of quantification – arbitrary by nature – it is reasonable to ensure that
✓ the categories of the verbal scale representing better reliability receive the higher value;
✓ and the differences (value ranges) between the values of each category should be equal
✓ we carry out the transformation in a way that can be measured (scored) on a ratio scale.

Make the substitution as follows!
✓ weak 1 point
✓ acceptable 3 points
✓ average 5 points
✓ good 7 points
✓ excellent 9 points

The quantified decision matrix looks like this:

Table 7. *Quantified decision matrix*

	X_1	X_2	X_3	X_4	X_5	X_6
S_1	**2000**	1550	**4,5**	160	1,88	9
S_2	1500	1460	**4,5**	160	1,70	5
S_3	**2000**	1595	3,6	**210**	1,61	7
S_4	1500	**1400**	4,0	70	**0,99**	3

In the next step, we have to produce unit-independent (transformed) data, and moreover, in such a way that the parameters also become the same direction.

There are several methods to solve this, we are discussing one of them here, the process of which is as follows:

1. Selection of ideal values

The ideal value must be determined separately for each aspect. One possible way to do this is the *value given by the experts*, and another way is the *value extracted from the table.*

Let's choose the latter case! Then the ideal value

- in the case of aspects to be maximized, the maximum of the column of the given aspect (x_j^{max});
- in the case of aspects to be minimized, the column of the given aspect will be the minimum (x_j^{min}).

The ideal values of our example are marked in bold in Fig. 7. in a table.

2. Perform transformation

Denote the original data by x_{ij}, and denote the transformed data by r_{ij}. The way to calculate the transformed data is as follows:

a) For aspects to be maximized:
$r_{ij} = x_{ij} / x_j^{max}$ (that is, the transformed value is obtained by dividing the original value by the maximum of the column)

b) For aspects to be minimized:
$r_{ij} = x_j^{min} / x_{ij}$ (that is, the transformed value is obtained by dividing the minimum of the column by the original value)

We will not present the detailed calculations for this example. The final result of the transformation is included in 8. spreadsheet. It can be seen that after the conversion, the larger value means the more favorable for aspects X_2 and X_5, which previously represented the criterion to be minimized.

Table 8. *Transformed decision matrix*

	X_1	X_2	X_3	X_4	X_5	X_6
S_1	1,00	0,90	1,00	0,76	0,53	1,00
S_2	0,75	0,96	1,00	0,76	0,58	0,56
S_3	1,00	0,88	0,80	1,00	0,61	0,78
S_4	0,75	1,00	0,89	0,33	1,00	0,33

With this, rather modified, transformed decision matrix, we can confidently start the maximin and maximax method.

15.2.5 The pessimist and the optimist choice

The pessimistic decision maker (Maximin method)

The essence of the method is as follows:

- the decision-maker pays attention only to the elements of the table and considers the different aspects to be of equal importance;
- the values are transformed to a comparative scale;
- for each alternative, *the pessimistic decision* maker considers the *worst value* associated with the alternative as the weak link and prefers the alternative with the highest value among them.

Process of the method:

a) find the value mi = min {x_{ij}: j = 1,....,m} for all I = 1,..... n (that is, the smallest value of the row of all alternatives);

b) we select the alternative with the value max {m_i: I = 1,....,n) (that is, we select the maximum of the smallest values and the alternative that “records” the maximum value).

The minimums for the example can be found in 9. marked in bold in the table.

Table 9. *Selection of the minimums for the alternatives*

	X_1	X_2	X_3	X_4	X_5	X_6
S_1	1,00	0,90	1,00	0,76	**0,53**	1,00
S_2	0,75	0,96	1,00	0,76	0,58	**0,56**
S_3	1,00	0,88	0,80	1,00	**0,61**	0,78
S_4	0,75	1,00	0,89	**0,33**	1,00	**0,33**

Based on the table, we = (0.53; 0.56; 0.61; 0.33). The maximum of these is 0.61, i.e. the type marked with S_3 will be the choice of the pessimistic decision maker.

The optimistic decision maker (maximax method)

✓ The optimistic decision-maker considers only the best values for each alternative and prefers the alternative with the highest value.

Process of the method:

c) find the value M_i = max {x_{ij}: j= 1,....,m} for all I = 1,..... n (that is, the largest value of the row of all alternatives);

d) we select the alternative with the value max {M_i: I = 1,....,n) (that is, we select the maximum of the largest values and the alternative that "records" the maximum value).

The maximums for this example can be found in 10. marked in bold in the table.

Table 10. *Selection of maximums for alternatives*

	X_1	X_2	X_3	X_4	X_5	X_6
S_1	**1,00**	0,90	**1,00**	0,76	0,53	**1,00**
S_2	0,75	0,96	**1,00**	0,76	0,58	0,56
S_3	**1,00**	0,88	0,80	**1,00**	0,61	0,78
S_4	0,75	**1,00**	0,89	0,33	**1,00**	0,33

Based on the table, M_i = (1;1; 1;1,1). This means that in the current situation, based on the maximax method, the alternatives are equivalent for the decision-maker, since each of them is the best from at least one point of view.

In this case, the choice can be made using another method, such as weighted score calculation. However, we will present this using another example, a location selection task, in the next subsection.

15.3 Site selection using the weighted score method

We can choose the best according to our criteria from among the site alternatives given by the method. In order to apply the method, we must first collect the possibilities and be able to formulate the evaluation criteria.

Steps to apply the method:

1. collecting alternatives (site options);
2. definition of decision criteria;
3. assignment of importance weights to the criteria;
4. numerical evaluation of the alternatives according to the individual criterias;

5. determination of the weighted score of each alternative as the product of the numerical evaluations given to the criteria and the importance weights assigned to the criteria;
6. ranking the alternatives based on the weighted scores.

If the alternatives to be evaluated already exist, we must be very careful when choosing the decision criteria (also known as aspects) and determining the weights assigned to them. The decision maker has to choose which features to consider and which not to.

The key concept of the decision-maker's thinking is the *aspect.* Things have countless properties, but only a few of them are taken into account by the decision maker. These are none other than the considerations of the decision-maker. After that, the only question is what distinguishes properties from essential properties (aspects). This can be determined using the following two criteria, which must be met:

1. It has a distinctive role in the given decision-making situation.
2. The change of the given property significantly affects the usefulness of the alternatives compared to the change of the other properties.

The first criterion, the distinctiveness condition, is that the alternatives can be separated on the basis of the examined property. If, for example, we can choose between two cars of the same color when buying a car, then the two alternatives are the same from the point of view of color, so this feature cannot be important, nor is it an aspect in this way.

An example of the second criterion is the effect of a change in the price of a product. If the increase in the price of a product affects the outcome of the decision, then the price is an essential feature, therefore an aspect.

The usefulness of the properties is always relative, so it can be interpreted in relation to each other, on the other hand, it is subjective, because it always depends on the decision maker.

There is a procedure that can be used to narrow the range of aspects and determine the importance weights at the same time. Let's learn about this procedure through an example!

Let's say that an international fruit juice company is planning to build a new warehouse in Central and Eastern Europe. Several site alternatives are available for the construction of the warehouse in different countries of the region. The management of the company wishes to select the actual site carefully and during conscious planning. The first step in the selection process is to determine the attributes on which each potential site will be evaluated. The project team responsible for the expansion held a brainstorming session to determine the criteria. The following list of properties was created as a result of the brainstorming:

- „A”: local fruit purchase prices
- “B”: average road distance of site from potential producers,
- “C”: the total installation cost of establishing a production plant
- “D”: specific costs of utility services,
- “E”: average road distance from current and potential customers,
- “F”: level of transport infrastructure,
- “G”: R&D capacities near the site,
- “H”: tax burdens,
- “I”: amount of labor,
- “J”: cost of labor,
- “K”: strictness of legal conditions.

It can be seen that, during the brainstorming session, the team collected 11 qualities that, in their opinion, are worth considering. However, this number is quite high. It is advisable to maximize the number of aspects at six. It is a question of which four properties to omit from the list of aspects. The selection is based on the relative importance of the individual properties. So we ask the project team to compare all possible pairs of properties in a table. If one member of a pair of attributes is judged more important than the other, that attribute should receive two points. In the event of a tie, one point is awarded to both attributes. The task can be easily done with the help of a table 11.

Table 11. *Determining the relative importance of properties by pairwise comparison*

Code	A	B	C	D	E	F	G	H	I	J	K
A		A2	A2	A2	A2	A1F1	A2	H2	A2	A1J1	A2
B			B1C1	B1D1	B2	B1F1	B2	H2	B2	J2	K2
C				C1D1	C2	C1F1	C2	H2	C2	C1J1	C2
D					D1E1	D1F1	D2	H2	D2	D1J1	D2
						E1F1	E1G1	H2	E1I1	J2	K2
F							F2	H2	F2	J2	F1K1
G								H2	G1I1	J2	K2
H									H2	H1J1	H2
I										J2	K2
J											K2

The filling “A2” in the intersection of row A and column B of the table means that the properties marked with A are more important than B, so property A gets two points. The marking “B1C1” found at the intersection of row B and column C means that the properties marked with B and C are equally important, so each property receives 1 point each.

The next step is to collect and sum up the total number of points which property received from the fields of the table. The total is entered in a new table, where the properties are listed in descending order according to the total score (table 12).

As indicated in the table, the six features with the highest relative importance score are kept as criteria (hereafter using the scores shown in the table as the importance weight), while the five at the bottom of the ranking are discarded.

Table 12. *A scoreboard of the relative importance of the features*

Code	Property name	Score
H	tax burdens	19
A	local fruit purchase prices	16
J	labor cost	14
C	the total installation cost of setting up a production facility	12
D	specific costs of utility service	11
K	strictness of legal conditions	11
F	level of transport infrastructure	10
B	average road distance of site from potential producers	9
E	average road distance from potential customers	4
G	R&D capacities near the site	2
I	amount of labor	2

In the next step, we create a table whose rows contain the selected aspects, its columns indicate the individual alternatives, and an additional column contains the importance weights (see table 13). The fields of the table include the evaluation of the alternative defined by the column according to the criteria defined by the row. The last row of the table contains the weighted scores of each alternative. Continuing our example, let’s look at a table that contains the evaluation of three imaginary countries (alternatives A, B and C) according to the criteria defined above. The ratings were made on a scale from 1 to 5, where “5” means the best rating and “1” the worst rating.

Table 13. *Site selection using the weighted score method*

Viewpoints	Weights	Alternatives „A”	Alternatives „B”	Alternatives „C”
tax burdens	19	4	1	3
local fruit purchase prices	16	2	1	3
labor cost	14	2	4	5
the total installation cost of setting up a production facility	12	3	3	4
specific costs of utility service	11	4	3	3
strictness of legal conditions	11	4	4	3
Weighted score		**260**	**204**	**289**

We have to multiply the evaluations given to site “A” by the weights for each aspect, and then add the values obtained in this way. So the weighted score for Site ‘A’ = 19 x 4 + 16 x 2 + 14 x 2 + 12 x 3 + 11 x 4 + 11 x 4 = 260.

It can be seen from the table that in our example the choice of country “C” is appropriate, since based on the evaluation of the decision-maker and the weights created by him, this alternative received the highest weighted score.

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