DECISION PREPARATORY METHOD FOR A COMPLEX COMPARISON OF PLAN-VARIATIONS OF BUILDINGS

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Abstract

The author of this paper shows the generalizable conclusions of a decision preparation method elaborated for a particular task, the system of plan selection based on value analysis. The method has been successfully applied in the practice of the METRO Transportation Developments and Investments Company for the comparison of plans of under casing line tunnels and deep metro stations, for choosing the optimum variant. The objective of this paper is to compose and weight the requirements of society, operator and investor, to determine the connections between them, and then by means of this system of requirements to compare the structure plans of 8 deep station variants of 3 under casing and 6 sites with different building conditions for the selection of the optimum variant.

The idea that the methods of investment activity, its technical means, organisation development did not keep up with the development rhythm of our society, our economy was formulated already in 1977 in Pécs, at the conference: "Value Assessment in the Construction Industry", also that this backwardness causes a growing brake in recent years, concerning economic growth [1].

This statement is valid also today. It is a regrettable fact that the realization period of investments is relatively long. With the majority of investments the actual input surpasses the estimated costs. At the same time the indices of economy are worse as compared to previously calculated results. With the new investments, that had been put into operation, the start-up time of production is longer than planned and often also with a higher than the planned work force viz. they can be operated at a lower live-labour efficiency.

The changes that occurred in recent years in the people's economy control aim at developing the production process. However, emphasizing intensive development instead of the extensive one viz. the efficiency of production, demands new control methods, planning means, that enable to measure the quality of utilization value and thus realize the conditions to analyze utilization value. (It is well-known that an increase in efficiency is but possible through well-founded decisions.) Decision preparation needs an elaboration of possible variations, a choice as to means for an assessment of acceptable solutions according to selection criteria. From among potential solutions several modes of selection are possible. The most characteristic ones are the following:

In situations demanding operative intervention a choice that can be characterized by optimal deliberation and based on improvisation is preferred. It may also be applied in a non-operative case when the importance of choice-consequences is relatively small or the process started through the decision is easily controllable in the following. Such instinctive decisions naturally carry the possibility of error, but their justification cannot be questioned, as they are necessary consequences of concrete decision situations.

In all instances, when the importance and weight of the decision is higher, its consequences cannot be calculated with the aid of simple means or it is rather difficult to control the process that has been started (in an extreme case it may be irreversible) the comparison of variations demands a complex, systematic weighting.

- In situations needing a rapid, but relatively well-founded decision, the choice may be on basis of a small number of decision criteria, by the classification of qualifying elements (e.g. it realizes — it will not be realized; suitable, mediocre, insufficient etc.). The method enables not to have to elaborate all possible variations, thus it cannot be utilized in more complex cases (e.g. to search for the optimum).
- For the comparison of rather complex structures, products, processes, projects, to make comparison of the possibilities possible, to select the optimal solution a more complex investigation (multiple criteria) investigation is needed, such as:
  - considering the qualitative effects not to be expressed in, cost and money;
  - assessment of many, differing weight components of use-value;
  - emphasizing the most advantageous solutions by comparing the advantages and disadvantages, viz. rejecting the unsuitable ones. The investigation of all these is not possible with a uni-dimensional target function. Thus the possible variations have to be measured in a multi-dimensional assessment field, on scales differing as to dimensions (scales that cannot be transformed into each other) and the obtained result will be the so-called "efficient as to complexity" solution.

The basic method of multi-criteria assessment methods comparing by weighting is the assessment on points. A common characteristic of the high number of methods elaborated is that they are able to weight properties not to be measured financially and even factors without any units of measurement, the so-called imponderables and also to recognize the most suitable variation. In practice, a high number of processes, models are used but all of them have been elaborated for the solution of part-tasks of a more complex problem-solving methods — for value analysis.

Value-analysis methods, solution techniques are an entity systemized scientifically on technical-economy bases. With its aid it is possible to determine the utilization value of complex systems, to select the variation that realizes the optimal solution at a minimal cost, concerning the unit of utilization value.

The endeavour to fulfill consumers' requirements, functional thinking, a parallel investigation of technical-economic questions are, by themselves and individually no novel basic principles. They were turned into a process-system that can be used successfully by the fact that their originator, L. D. Miles, summarized them into a unified system that has a logically closed train of thoughts.

As known, value analysis, conceptualizes the object of investigation as a summarized utilization value described by a multiplicity of features. These are mutually influenced by each other, indicate a dynamic development as an effect of external factors and fulfill a social unit through well-defined social requirements.

A complex of four factors figures in value analysis:

— The requirements deciding about the utilization value;
— The object, viz. the subject of analysis that has to fulfill in an optimal way the required utilization value;
— The methodology of value analysis by the aid of which the optimal efficiency may be found in the process of supply;
— The subject, in other words the work group that realizes the methodology and also applies it conscientiously: the team.

The work realized by the work group (team) guarantees a complex, professional solution of the problem as measuring assessment factor scales (classifying, ranking scales) cannot be objectively compared, to assess their joint impact on a single scalar function can only be achieved subjectively, by considering the opinion of experts and those interested in the effects of interventions [2].

In the beginning value analysis had been applied for the post-improvement of the value of existing products. On basis of practical experience, planning based on Value Analysis has been accepted as it was recognized that the majority of excess costs originates from construction. Value analysis realized in the planning period makes the evolving of excess costs impossible. The original method became known by the name of Value Analysis while planning on the basis of value analysis is known in international literature as "Value Engineering".

The third method to determine the most suitable function-cost relation is "Value Control". It does not aim at developing a more suitable solution of the investigated product, object or process than an earlier one, but selects the optimal one from products realized by differing technologies, materials, methods, at different costs.

Since this procedure system has been developed a number of novel kinds became known. The train of thought already mentioned is characteristic in all of them, the difference is to be found in the object of investigation, the field of problem-approximation, the applied methods.

A means of development activity — investment — is a combination of a high number of demands, functions and costs, thus it is suitable for a complex investigation through the procedure system of value analysis.

The development of investments can be influenced by value analysis defining cost input in the following stages already:
— when preparing designs,
— while producing construction materials and installations,
— when developing construction systems,
— when designing technology,
— in the organisational area.

The potential success of intervention is inversely proportional to time and after a certain construction stage no further utilisable success can be reckoned with. However, value analysis carried out during the investment programme, promises an important utilisation value growth, a cost economy. Its highest success (in theory) may be expected by the investor (the operator, utiliser), as well as by society in general, when applied in the stage prior to the investment programme.

The basis of this type of investigation is a specificity of value analysis: by breaking down the product into functional sub-units, parts of structures find themselves in one group which, though locally far from each other still serve to satisfy the same need, add to the realization of the same function.

In the following a model will be introduced which is suitable to select the most suitable variation from among different design variations of buildings from the point of society as well as the demands of those participating in its operation and realization.

To realize the task it is most expedient to work with a multi-criteria complex investigation method based on a value analysis which solves difficult problems by posing simple questions with a great coherence, through conscious control of creative power.

The model supposes a manifold, far-reaching demand system of the building, a complex aggregate of functions, and analysis is realized on basis of the weighted demand-system.

During the investigation one has to start from the basic purposes of the building. To these are attached concrete urbanistic potentialities, well-defined economic circumstances, enterprise-policy aims, a system of demands in a socio-political framework which can be broken down into:
— demands to be fulfilled without any condition,
— demands to be fulfilled conditionally.

Non-realization of any of the demands to be fulfilled unconditionally means a fail of the basic purpose. The demands that can be fulfilled on condition form, in case of major investments a multistage line. The demands of organisations situated on individual levels (builder, operator, investor, designer, executor, producer . . .) originated from the fact that they try to fulfill the expectations of those one stage above them. Downwards the proceeding demands can be quantified more and more. The most difficult is to formulate the highest level social expectations, especially in case of infrastructure investments where practically not even the person of the "customer" is completely clarified.

There is a dialectic relation between those participating in the investments. The highest utilisation value (relatively) at an investment achieved at the lowest input has to be realized at an optimal economy for the participants. The designer can carry out his work well only in case if he knows the expectations of the investor, at the same the executor (producer) takes also into consideration his existing material-, technical basis, his technology, his development possibilities.

There is therefore no contradiction in the fact that if also the executor is independent, he will appear on the scene with a high number of demand. The technical-technological basis of the executing enterprise, if not absolutely decisively determining, is still an influencing factor as to the applicability of construction technologies.

The formulation of demands should be of general validity. It is to be considered independent from preciously used construction technologies, materials, modes of execution. This is quite natural, as the product — in a given case a building — has functions that are the demands of the consumer (society, operator, investor), the solution (construction, means, costs) is determined by the producer.

The "general validity" formulation makes possible a free putting forth of creativity, though, an exploring of value-reserves, as well as, at the present development of productive means, to design structures, construction technologies as yet not known, or, due to the non-readyness of the executors not yet applicable. The aggregate of demands concerning major investments should most expediently be investigated broken down into social, operative, investment and executor-sub-systems, but there is not always a unanimous hierarchic relation among them. In such a case, the part-aggregates should not be treated in a subordinate relation, but as independent systems of demand and a relation should be bridged between them in the course of weighting.

Several methods may be used to determine the weight numbers characteristic of individual demands. The most common is the preference-matrix comparison method. Its essence, formulated in a general way is shown in the following table.

The sum of numbers figuring in the rows of the preference matrix (assessment number in the following) is in direct proportion to the weight of the

Table 1

	1. Demand	2. Demand	j. Demand	n. Demand	INDIVIDUAL ASSESMENT NUMBERS
1. Demand	a_{11}	a_{12}	a_{1j}	a_{1n}	b_1
2. Demand	a_{21}	a_{22}	a_{2j}	a_{2n}	b_2
i. Demand	a_{i1}	a_{i2}	a_{ij}	a_{in}	b_i
m. Demand	a_{m1}	a_{m2}	a_{mj}	a_{mn}	b_m

$m = n$
a = 1 if the demand figuring in the row is the more important
a = 0 if the demand figuring in the column is the more important
if $a_{ij} = a$, then $a_{ji} = 0$
if $a_{ij} = 0$, then $a_{ji} = 1$
b = individual assessment number $b_i = \sum_{j=1}^{n} a_{ij}$

assessment factor, as supposed by the person giving his opinion, but is not identical with the weight number of the demand. It reflects but an individual opinion. (The former figure shows the sample of the individual ballot paper.) The aim of comparison by pairs is a logical analysis. However, no equal depth of knowledge can be expected from individuals in all relevant special fields. The weight number is thus a result of the collective standpoint of those knowing different special fields best, based on an individual opinion; this is the average of the assessment figures determined on individual ballot papers.

In the course of calculating the average there are several possibilities to take extreme opinions into consideration.

It has to be accepted that despite an endeavour to objectivity of the method, it has certain subjective features and also that the cause of subjectivity is not a conscious distortion of the weight of individual assessment factors, but experience gained in work among differing conditions. The method builds the calculated average into the weight numbers without any modification.

Independently from the assessment numbers and the amount of the average, leaving one each from among the smallest and the biggest assessment numbers out of consideration, it is the aim to form the arithmetical mean of the remaining assessment numbers.

The advantage of the method is the more simple mode of calculation, while its disadvantage is, that in case of opinions considered to be extreme, it does not investigate their relation to the average and the remaining assessment numbers.

The iteration weight computing mode takes into consideration how the assessment numbers relate to the group opinion. In the first stage, the mathematical middle of all assessment numbers has to be computed and then the ones are to be set off that do not reach a previously determined proportion (e.g. 20%) of the average and/or exceed it by a previously determined value (e.g. 80%). Without the values set off, the averages have to be repeated until there are assessment numbers among the ones outside the freshly computed average determined proportions. The weight number of demand is the average computed in this way.

The final purpose of matrix comparison is to determine the weight of all preferences in relation to each other. However, it is not sufficient to apply the method in comparative investigations of major investment demand systems. This has two causes:

— The high number of assessment standpoints does not permit their comparison in a single matrix. (n number of demands necessitates n^2 number

Table 2

	I_{11} Demand	I_{12} Demand		I_{1i} Demand	I_{21} Demand	I_{22} Demand		I_{2j} Demand					I_{k1} Demand	I_{k2} Demand		I_{km} Demand
I_{11} Demand	1	1	1	1												
I_{12} Demand	0	1	1	1												
	0	0	1	1												
I_{1i} Demand	0	0	0	1												
I_{21} Demand					1	1	1	1								
I_{22} Demand					0	1	1	1								
					0	0	1	1								
I_{2j} Demand					0	0	0	1								
									1	1	1	1				
									0	1	1	1				
									0	0	1	1				
									0	0	0	1				
I_{k1} Demand													1	1	1	1
I_{k2} Demand													0	1	1	1
													0	0	1	1
I_{km} Demand													0	0	0	1

Within the preference matrix
demand I_{k1}, is the demand within demand group K which achieved the highest assessment number within its own demand group,
demand I_{k2}, is the demand within demand group K, which, after weighting within its own demand system is a demand set off with an intermadiate assessment number,
demand I_{km} is the demand within demand group K which, after weighting within its own demand system, is the one that achieved the lowest assessment

comparisons, per assessing persons, and this, in case of a demand number exceeding 25—30 is practically not realizable.)

— The aggregate of demands (social, operative, investor, executor) forms several groups, with specific assessment standpoints in each concerning independent areas. Thus, in the course of weighting with a single matrix, the representative of each special field would be forced to take up a position also as to demands, that are far from his knowledge.

Weighting, therefore, has to be realized in two stages. The first step is to determine one of the components of the weight numbers (C_1 in the following) by initiating one by one experts of individual speciel fields by demand-groups.

The second component (C_2) of the weight number is to be computed the following way.

Within a demand group weight number components C_1 determine an order of importance. On basis of this order, the preference characterized by the highest and the lowest weight number has to be set off, as well as an other two or three, depending on the number of indicated demands. The demands set off are to be placed into a new matrix in a way that the assessment standpoints from an indentical group, based on the order taken up in their own demand system, are to be preferenced already previously, as related to each other. This is to be undertaken in a way that the elements pertaining to an identical demand aggregate are to be written in the new preference matrix in the order of their importance, following each other according to the demand that had achieved the majority of assessment points, and, above the diagonal line, *1* is to be written in the meeting point of demands, while *0* below the diagonal line.

In the new preference matrix, comparison has to be undertaken in an identical way with what has been described, with the cooperation of a work group where the members are in full knowledge of the content of all demands.

After analyzing the combined preference matrix, the second component (C_2) of but 4 or 5 standpoint weight numbers can be achieved by demand groups. All other assessment standpoint part-weight numbers can be achieved by interpolation.

All assessment standpoints are characterized by two weight number components (C_1 and C_2) determined according to the above. The weight number expressing the importance of the investigated demand is a percentual value of their product as related to the possible maximum.

Expressed mathematically:

$$S_i = \frac{C_1(i) \times C_2(i)}{n_1 \times n_2} \times 100$$

where S_i = the weight number of demand i

$C_1(i)$ = the weight number component achieved by demand i within its own demand system

$C_2(i)$ = the weight number component of demand i;computed on basis of the combined matrix and interpolation

n_1 = is the number of assessment aspects of the specific demand system comprising demand i

n_2 = the number of demands set off, figuring in the combined preference matrix.

The next step of the comparative investigation is to qualify the designs according to demands. Qualification is an investigation of all variations, according to all assessment aspects. The method is to set off individual aspects from the others, by passing step by step along all demands and to evaluate as to what measure the different variations satisfy what has been formulated in the specific demand.

Qualification means to classify the investigated design variations according to demand. This "score" is the qualifying number.

By multiplying the qualification number with the previously determined weight number of the demand the importance of assessment aspects can be taken into consideration. By qualifying according to all comparison criteria of individual design variations and then summing up the qualifying scored multiplied with the weight numbers a value is achieved that expresses as to what measure the investigated design variation satisfies in its entity the aspect

Table 3

	S_1		S_2		S_p		S_r				
1. Plan variation	m_{11}	t_{11}	m_{12}	t_{12}	m_{1p}	t_{1p}	m_{1r}	t_{1r}	T_1	K_1	E_1
2. Plan variation	m_{21}	t_{21}	m_{22}	t_{22}	m_{2p}	t_{2p}	m_{2r}	t_{2r}	T_2	K_2	E_2
U. Plan variation	m_{u1}	t_{u1}	m_{u2}	t_{u2}	m_{up}	t_{up}	m_{ur}	t_{ur}	T_u	K_u	E_u
V. Plan variation	m_{v1}	t_{v1}	m_{v2}	t_{v2}	m_{vp}	t_{vp}	m_{vr}	t_{vr}	T_v	K_v	E_v

S_p = weight number of demand p

m_{up} = qualification number of demand p according plan variation U. $m = (0) \rightarrow (10)$

T_u = complex advantage of plain variation U taking all (number r) demands into consideration. $T_u \sum_{p=1}^{r} t_{up}$

t_{up} = the "capability" of plan variation U, according to demand p. $t_{up} = S_p \times n_{up}$

K_u = cost of variation introduced within design U

E_u = the success measuring number of plan variation U. $E_u = \frac{T_u}{K_u}$

E_{max} = the success measuring number of the optimal plan variation formulated in the demands.* However, it should be kept in mind as to what input cost is needed by the investigated variation to achieve this complex advantage. Success (E) is the quotient of the complex advantage (T) and the costs (K), and expresses the amount of advantage achieved by what unit quantity cost of the variation. The above is summed up by the following table.

In the course of this complex comparison, it was factually applied in a series of major investments e.g. Metro-line building, in the Hungarian capital.

In the past, only part-assessments were prepared concerning a few aspects (live work content, material proportion, etc.) for the purpose of economic investigations concerning tunnels and station structures. Once only, was a comparison made as to station structure types, and that for the stop at Marx square. In the discussion that had developed between the investor and the designer, a demand cropped up to compare the costs of a sub-pavement stretch and a stretch at a considerable depth. The investor tried to draw conclusions from cost-data of two stages built practically at the same time, a subpavement one and a one built at deep level. The cost-comparison could not give a correct result, as there was no possibility of free choice between the two, different depth stages (Nagyvárad square—Határ street and Marx square—Arany János street.) The manifold analysis would have necessitated that at least a sub-pavement and a high-depth plan should be prepared for the same line-part, this, however, was impossible because of the then investment system.

A complex analysis is to make up for the missing technical-economic comparisons.

Along the entire area of the Metro-line several possibilities are open:

- determining the optimal metro-line construction (subpavement or at deep level),
- comparison of planned tunnel structures, building technologies,
- investigations to improve the success of tunnel (and/or station) structures, structural units,
- analysis of the investment-preparation procedure.

From the point of enterprise policy, development aims of the investor (from among the formerly mentioned) a value-analysis comparison (value control) of the plan variations of tunnel and/or station structure technologies would have been the most suitable.

To determine the constructions to be investigated the metro-construction-system had to be investigated. This unites, basically, three construction groups:

- line constructions

* In this sense dr. Géza Jándy uses the concept of "Index with a complex advantage." in his work: Assessment possibilities in the preparation of socio-technical interventions, in systemtechnical problem-solving.

— stations
— operating rooms
and buildings pertain that are supposed to satisfy
— normal (transport)
— special (civil defense)
— operation demands.

Buildings serving transport functions may be situated both beneath and above the earth, or also on bridge-structures, but due to seclusion because of special circumstances, they are bound to tunnels beneath the earth, to stations and other engineering objects also beneath the surface.

The two great groups of sub-soil systems are constructions built
— beneath the surface, from a trench opened from the surface, and
— in a certain depth, with the aid of mining methods.

Following the suggestion of the group undertaking the work, the first investigation covered the line-tunnel unit of the metro construction system beneath the pavement.

The choice was indicated by the following:
— at the start of the analysis work, the construction of the Metro between Élmunkás square and Árpád bridge and the preparation of the part between Árpád bridge and Újpest Bajcsy-Zsilinszky street was underway. Both part-lines were constructed under the pavement.
— The major part of realization was made up by the line-tunnels,
— as regards their function, they consist of the least complex part units, of many similar constructions and building technology. In this way the task may be simplified to the investigation of a line cross section —practically one linear metro line tunnel.

The other task to be solved was to elaborate a comparison method concerning stations of deep level lines.

The choice, this time was substantiated by the following:
— the comparative investigation was to help preparing the first stage of the line between South Buda and Rákospalota,
— the investor has to select the most suitable solution from a relatively high number (8) station structure variaties,
— the comparison was made more difficult by the fact that the stations are to be built at different geological and hydrological conditions,
— a high proportion of the realization costs is made up by building the deep level stations,
— regarding its functions, this is a complex construction and determining the structure satisfying manifold demands in an optimal way demands a far-reaching investigation.

In the course of the latter investigation it came to the comparison — at different conditions — of several identical function constructions that may be determined by identical demands and thus the method introduced earlier had to be modified.

It spoke against the obvious solution, viz. that the weighting of all demands should be carried out again and again concerning all work places with different specificities, that the amount of manual work would not be in proportion to the result that it could bring, whereas concerning the demands that are at a lesser dependency with local potentialities a multiple comparison also contains the danger of inconsistency originating from the involuntary subjectivity of those giving their opinion.

Realizing this danger and also to lessen the quantity of work to be done, the model of investigation breaks down the series of demands into those that are

— independent from the locality of building and
— that are specific as to the locality of building and presents both groups in the came, common preference matrix.

The steps of comparison within the matrix differ from the previously introduced ones in that weighting is done in two stages.

The first step was to compare the assessment aspects independent from building site specificities, and in this way there is no need to be occupied with demands specific to the site of building. The result is one of the individual assessment numbers — a component (b_A), constant at every building site.

In the following the comparison of building site specific demands is carried out. The analysis has to be done in individual matrices as many times as there are building sites that can be characterized by different specificities.

The calculated value, b_B^K, is the second component of the assessment number characteristic of building site K of the investigated criterion.

Determining one by one the assessment number of individual demands the value concerning demand i for building site K is the sum:

$$b_i^K = b_{Ai} + b_{Bi}^K$$

To select the most suitable variation, the plan variations have to be qualified according to demands. This qualification has to be done but once for each plan variation, as the "potential" is not specific as to building site but as to structure. Qualification values (m) figuring in the index (T) of the complex advantage are constant as to building site and also the costs (K) characteristic of individual variations are identical.

The complex advantage index (again differing as to building site) has to be determined for the plan variations with weight numbers different by each building site, and then, by taking into consideration the constant cost values, the result obtained will be the number characteristic of efficiency. This also varies according to building site and expresses, as a result, that the most suitable solutions in areas with different features are not necessarily identical. The model is not only suitable to accomodate for specificities differing in space. With its aid also the measure of importance of demands with a weight changing in time can be determined. (Such as, e.g. aspects concerning foreign currency demand, the necessary enterprise investments or those in connection with diversion of traffic.) With plan variations of similar character building, when comparing them there is no need to compare all investigation criteria of demands with a weight depending on time, only the aspects modified because of changed conditions have to be emphasized, and the second step of weighting described earlier has to be repeatedly carried out.

The investigation model introduced in the above is suitable to compare variations of buildings already known at a design level, to select the most satisfying variation of society, operator, investor and realizer. The Value Control method is a passive form (relatively) of value assessment. It regards the object of investigation from the outside, without a favourable demand satisfying capacity in the given period, without the purpose of developing a cost relation. Its further improvement possibilities, however, are inherent as it gathers together the obstructing factors already in the information stage which hinder an economic realization of the construction under investigation, groups the problems emerging at the time of realization and operations, explores the areas that may be sources of success-reserves.

However, to realize the demands that had been formulated is only possible through a detailed knowledge of functions, and after a severe examination of their fulfilment and their costs, by setting free creative fantasy. The investor may play an active role here if, instead of a passive comparison he spurs the designer to active action and by letting the designer have the prepared weighted demand system, encourages him to design a construction fulfilling at a maximum the demands that had been formulated. A free flight of imagination may be helped by inviting tenders after making known the system of demands and their weight. Knowing such demands can serve as orientation for the applicant and the elaborated system of analysis may aid a more objective judgement of the works submitted.

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