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The TRIZ method in determining individual heating costs

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Abstract: The assumptions used in the calculation methods for housing heating costs are described in this paper. The results of calculations are influenced by the values of coefficients related to the location of flats in a building. A technical contradiction, a reversed technical contradiction and a physical contradiction were formulated. Based on the indicated inventive principles, the calculation methods for individual heating costs were analysed.

Keywords: heating costs, technical contradiction, reversed technical contradiction, physical contradiction, temperature

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Introduction

TRIZ (Russian: теория решения изобретательских задач, literally: "theory of the resolution of invention-related tasks") is "a problem-solving, analysis and forecasting tool derived from the study of patterns of invention in the global patent literature". It was developed by the Soviet inventor and science-fiction author

Genrich Altshuller (1926-1998) and his colleagues at the beginning of 1946. In English, the name is typically rendered as "the theory of inventive problem solving" and occasionally goes by the English acronym TIPS (https://en.wikipedia.org/wiki/TRIZ). Genrich Altshuller discovered that all industries utilized the same underlying inventive principles. These principles could be generalized and universally applied. These days, inventive problem solving can be learnt and taught. The main TRIZ tool used in this research is the 40 principles of TRIZ. One of the tools which evolved as an extension of the 40 principles was a contradiction matrix (Novismo, 2019) in which the contradictory elements of a problem were categorized according to a list of 39 factors which could impact on each other.

TRIZ was virtually unknown in the West (Fey & Rivin, 2005) until a translation of one book by Altshuller was published in 1984. While the book initiated a few devotees to TRIZ, a poor translation minimized its impact.

In 1991, a TRIZ-based software package, developed by the Invention Machine Corporation, was demonstrated in New York and commercially launched. Although the software attracted significant interest, it was, essentially, only a series of illustrated problem-solving analogies that failed to reveal the thought process required for the effective application of the methodology itself. Since the software's users were by and large unfamiliar with the thought processes behind TRIZ, they were unable to fully utilize the power of this methodology.

Throughout the 1990s, small consulting groups began to appear in the West, usually founded by immigrants from the former Soviet Union. Their principals were experienced TRIZ practitioners. Many of those pioneers were students and collaborators of TRIZ's founder, Genrikh Altshuller. Those groups were solving problems for their client companies and training customers in TRIZ fundamentals. As a result of these efforts, leading corporations in the U.S. and overseas have reported significant benefits from using TRIZ.

Today's TRIZ contains numerous problem analysis and concept generation tools, not all of them well formalized. Learned knowledge should be enriched with practical activities.

According to Altshuller, a problem ought to be termed as concise as possible.

1. Materials and methods

Today the European building stock consumes approximately 40% of primary energy and it is responsible for 36% of the EU greenhouse emissions. The Energy Efficiency Directive 2012/27/EU is the cornerstone of the legal framework for accurate metering and billing of individual consumption of heating/cooling and domestic hot water in multi-apartment and multi-purpose buildings in the EU. This requires the introduction of consumption-based cost allocation and informative billing of heating, cooling and hot water in multi-unit buildings, subject to certain conditions. Individual metering and billing permit a fairer system of repartition of the energy costs among the occupants of multi-apartment buildings based on actual energy consumption rather than estimation done according to the size of the dwelling.

In a multi-apartment building, some dwellings may naturally be colder because of their unfavoured location (e.g. located under the roof, over an unheated parking space, at the corner of the building, oriented north, etc.). Moreover, due to absence of thermal insulation between adjacent apartments, thermal energy can fairly easily flow between the apartments. Therefore, the individualisation of heating cost might not be perceived as fair if based exclusively on individual meter/heat cost allocator readings. Different countries apply diverse approaches to this heat cost allocation aspect (e.g. use of specific correction coefficients, the share of overall costs allocated based on readings, the use of minimum and maximum limits for the share of costs allocated to an individual unit, etc).

Correction factors can be calculated per flat or per single room, as in the Romanian and Hungarian case. Moreover, some Member States provide in the legislation the correction factors in specific tables (e.g. Romania), taking into account the position of the building unit, in others they are calculated for each building by independent energy experts (e.g. Latvia, Slovenia). The use of correction factors for the allocation of heating costs in multi-apartment buildings is forbidden in Austria, Germany and Italy (Castellazzi, 2017). Michnikowski & Skiba (2014) and Michnikowski & Grzywacz (2015) presented the criteria for checking the correctness of heating costs settlements based on the heat cost allocators.

In Denmark, correction factors are used to compensate heat transfers between dwellings as well as to adjust the heating costs of apartments located in the outermost parts of the building (Robinson, 2016). This is because these apartments require more energy for heating, and the purpose of the correction factors is to divide heating costs fairly. Radiator sizes, consumption in previous years and values from comparable buildings can be used to determine correction factors, if the original heat loss calculation is not available.

Correction factors must be updated whenever the building is significantly changed and can be disregarded only if heat loss has already been taken into consideration when determining the rent or the evaluation would be too expensive (or unnecessary). The correction factors for a larger multi-apartment building are in the range of 0 for apartments centrally located in the building to –50% for apartments on the top floor at the gable wall.

In Hungary the cost allocation is directly managed by the condominium owners assembly; when heat cost allocators are installed, at least 30% up to a maximum of 50% of the consumed heat quantity shall be divided between the units on the basis of the volume of the unit. The remaining quantity shall be divided based on the information provided by heat cost allocators, taking also into account room orientation correction factors (Table 1). Correction factors are calculated per every room. Installing the allocators in building common areas is not required; the owner assembly can decide how to distribute the heat cost for these areas. The numerical example (Castellazzi, 2017) gives:

A = 4367 measured heat consumption
B = **2865** heat consumption in proportion to heated m^3
C = 7232 total heat consumption before correction

D = 70% correction factor
E = 0.7·4367 + 2865 = 5922 this is final heat consumption after correction.

To calculate heat consumption properly in proportion to heated m^3, the indications of the heat meter and the properties of electronic cost allocators expressed by the E_B coefficient must be taken into account.

If the value of E_B is unknown, in the calculations the value of coefficient E_B should be used 1 (Adamski & Rynkowski, 2015).

Table 1. Room position/orientation correction factors used in Hungary (Robinson, 2016)

Room position in the building	Correction factors
Ground floor no premises underneath	–15%
Ground floor with unheated premises underneath	–10%
Unheated passageway or premises beyond gateway	–15%
Premises beyond unheated ground floor	–5%
Premises next to unheated stairway or corridor	–10%
Premises directly beneath the flat roof	–20%
Premises beneath non built-in attic	–15%
Beneath built-in unheated attic	–10%
Corner room with at least 2 outward surfaces	–10%
Northern side correction	–5%

The use of correction factors for the allocation of heating costs in multi-apartment buildings is mandatory in Denmark, Czech Republic and Lithuania, it is forbidden in Austria, Germany and Italy, while in France and Poland their application is voluntary (Castellazzi, 2017). Regarding Poland, this information is incorrect, because correction factors for the allocation of heating costs are mandatory.

For comparison, many years ago the correction factors for the allocation of heating costs were regarded in the calculations in Austria.

Correction factors, marked usually as R_m or *LAF* can be calculated per flat or per every single room, as in the Romanian and Hungarian case. Moreover, some Member State provides in the legislation the correction factors in specific tables (e.g. Romania), taking into account the position of the building unit, in others they are calculated for each building by independent energy experts (e.g. Latvia, Slovenia).

Adding virtual heat units to the values resulting from the heat meter readings reduces the price of the heat unit c_1 to the value determined by the equation (Kozydra et al., 2019):

$$c_1 = 1.1628\, c_c \frac{1}{E_B} \tag{1}$$

where:
c_1 – price of the heat unit [zł/unit];
c_c – price of the heat [zł/kWh];
E_B – base sensitivity [unit/kWh].

Room position/orientation correction factors reduce the number of heat units. Hence,

$$c_1 = 1.1628\, c_c \frac{1}{R_{mB}\, E_B} \tag{2}$$

where R_{mB} – average value of R_m for the whole building.

The use of correction factors increases the price of a heat unit. Excessively high price per unit of heat causes that the settlements of heating costs do not reflect the value of heat consumed. Thus, the energy, supplied to the rooms with the correction factor, is paid by other residents.

In Poland, room position/orientation correction factors are marked as R_m or *LAF* coefficients, previously were determined on the basis of tables. Currently, they are determined on the basis of calculated heat loss values in individual apartments.

Excessively high prices of a heat unit does not correspond to the price of 1 kWh of the heat and leads to determining the amount due for heating apartments, which does not correspond to the value of heat used (Adamski & Myszkowska, 2018). Hence this follows a technical contradiction.

2. Technical contradiction

The following technical contradiction can be formulated:

If [specific action]

(we take into account the location of the premises and) we use the R_m coefficients of the location of the premises in the body of the building,

then [positive change of technical system parameter X]

at calculated outside air temperatures and achieved radiator power in accordance with the calculation values of the heating charges are in accordance with the value of heat consumed

but [negative change of technical system Y parameters]

under real conditions, the heating charges do not match the value of the heat consumed.

Generalization of parameters:

X: 24 – loss of information
28 – measurement accuracy
27 – reliability
30 – object – harmfully affected
31 – object – harmfully generated

Y: 27 – reliability
35 – adaptability or versatility
30 – outside air temperature as a harmful factor

This contradiction can be expressed somewhat differently:

If we use the Rm coefficients of the location of the premises in the building block,
then increased heat consumption of extreme apartments is taken into account
but reliability of calculations is reduced
(unreliability of calculations increases).

The Contradictions Matrix is given in Table 2.

Table 2. Contradictions Matrix and the indicated inventive principles (*own research*)

Parameter to be improved X	Deteriorating parameter Y		
	27 – reliability	35 – adaptability or versatility	30 – adaptability or versatility
24 loss of information	10, 28, 3	22, 10, 1	
28 measurement accuracy	5, 11, 1, 23	13, 35, 2	28, 24, 22, 26
27 reliability		13, 35, 8, 24	27, 35, 2, 40
30 object – harmfully affected	27, 24, 2, 40	35, 11, 22, 31	
31 object – harmfully generated	27, 2, 40, 39		

The following Inventive Principles were selected from Table 2:

5 – Merging / joining / embedding
a) Combine similar or identical objects

11 – Beforehand cushioning = Prepare in advance measures to mitigate the adverse effects of the facility

1 – Division
a) Divide the object into parts independent of each other (a ship built, made of removable / replaceable bulkheads)
c) Increase the degree of object fragmentation (multi-piston engine of internal combustion)

23 – Feedback principle
a) Enter feedback to improve operation or process
b) If feedback is already applied, change its intensity or frequency

10 – Preliminary action. Prepare in advance measures to mitigate the adverse effects of the facility
a) Ensure – in part or in full – the required change to the object before it is needed
b) Arrange the objects in advance so that they can start operation from the most convenient place and without wasting time on their movement

28 Replacement of mechanical diagram – c) Move from static to dynamic fields and from unstructured to structured fields.

3. Inverse technical contradiction

Inverse technical contradiction could be formulated as follows:

If we assume $R_m = 1$, i.e. the coefficients are not used and do not effect on the calculations

then reliability of calculations increases

but greater heat consumption of perimeter apartments is not regarded

Table 3. Altszuller matrix for inverse technical contradiction (*own research*)

Parameter to be improved X	Deteriorating parameter Y	
	24 – loss of information	28 – measurement accuracy
24 loss of information		24, 26, 28, 32
27 reliability	10, 28	32, 3, 11, 23

The Inventive Principle 32: Colour changing; change of the degree of object transparency was selected from Table 2. This could be understood not directly, but as additional insulation of perimeter apartments.

4. Physical contradiction

Physical contradiction could be formulated as follows:

We use the R_m coefficients of the location of the premises in the building block,

to regard increased heat consumption of extreme apartments

and

we assume $R_m = 1$

to increase the reliability of calculations.

The reliability of calculations means the result of calculations of the heating costs of individual apartments, which corresponds to the value of heat consumed.

Conclusions

The TRIZ method shows the possibilities of inventive solution to the problem. The indicated principles of the invention suggest following solutions:

- 5: combine similar rooms;
- 10, 11: add units to read values from allocators;
- 1: applying Rm coefficients to individual corner rooms, and not to the whole apartment;
- 23: to control the values read from the allocators;
- 32: additional insulation of perimeter apartments

The TRIZ method is a useful tool to indicate the direction the search for innovative solutions should move in.

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