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Research paper

Determinants of substitution in the environmental aspect of sustainable construction

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Abstract: Environmental protection is one of the objectives of the implemented concept of sustainable development and circular economy. The construction industry and its products (building objects) have a large contribution in negative influences, therefore all actions limiting them are necessary. One way of doing this is to apply substitution to existing unfavourable solutions, both in terms of construction and materials as well as technology and organization. The aim of the article was to determine the key factors conditioning the use of substitution at each stage of the investment and construction cycle, leading to environmental protection. The research paid attention to the use of substitute recycled products. The defined factors were subjected to a SWOT analysis and then, using the DEMATEL method, cause-and-effect relationships were identified that determine development in the application of substitution in the environmental context of sustainable and closed-cycle construction. The analysis was carried out by using a summative, linear aggregation of the values of the position and relationship indicators.

Keywords: substitution, sustainability, circular economy, recycling

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1. Introduction

Sustainable construction aims to meet the demands and needs that are placed on this sector of the economy, while reducing negative environmental impacts. Systems are being implemented for the execution and supervision of construction works, with the aim of reducing the undesirable impact on the environment. These are referred to as environmental certificates. In Poland, the most popular are LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method). We should also mention the DGNB system (Deutsche Gesellschaft für Nachhaltiges Bauen), which is less popular globally, but has a high profile in Western Europe [1]. The production of construction products using recycled materials (commonly in road construction) is developing, as well as the construction of buildings using recycled materials as basic construction products, e.g. "earthship" buildings [2]. Energy-efficient and passive buildings, so-called Zero Energy Buildings [3] and Green Buildings [4], with minimization of energy demand (from outside) at the operational phase, have become a popular solution. It is accepted that at each stage of the life cycle of a building the negative impact on the environment should be reduced.

Every construction product used in a building requires energy. At the stage of obtaining raw materials, their processing (production), delivery to the construction site, erection, operation, ending with demolition – each of these stages leaves a negative impact on the environment, most often measured as the so-called "carbon footprint" [5]. But demolition does not necessarily mean 'the end' for a construction product. Demolition can be the next step in the re-obtaining of a construction product. This will be less energy-intensive than producing it from raw materials, in particular those based on non-renewable resources. The reuse, processing or addition of demolition material will constitute its pro-environmental material substitution. Enabling the effective use of materials obtained from demolition requires, among other things, changes in the legislation on the marketing authorisation of construction products [6] but also a change in the approach of designers and, above all, the approach of investors. At the stage when the need arises, it is essential for investors to be aware of the need to reduce the negative impact of the construction sector on the environment. A practical solution to adapt investments to these assumptions is precisely the phenomenon of substitution of construction products. Product substitution may take place at any stage of the life cycle of a works. Depending on the interference of the substitution with the construction solution, it will be possible to distinguish cases which lead to substantial changes and those which will be treated as non-substantial.

Substitution can also be understood as a change of technological processes during the implementation of a construction project or simply the use of local raw materials, products and services, thus minimising the negative impact of transport and shortening the logistical process. The choice of alternative materials or construction technologies from traditional, commonly used ones is based on an analysis of the EcoPoint indicator [7]. Such approach is consistent with the concept of sustainable development (SD), including sustainable construction (SC). On the other hand, the use of recycled materials and products, recycling of waste "fits in" with the concept of the circular economy (CE), and jointly with the so-called closed (circular) cycle construction (CC) and brings more benefits to the currently implemented socio-economic concept [8].

The aim of the article was to determine the factors conditioning the use of substitution at each stage of the investment-construction cycle, taking into account the principles of circular construction, i.e. meeting the principles of sustainable construction and circular economy. Attention was paid to the use of recycled products in substitution. In this article, the authors focused on identifying factors characterising the use of substitution and its impact on the environment. These factors were analysed using the SWOT method [9], which made it possible to determine the factors that are the strengths and weaknesses of the use of substitution in the investment process, as well as the opportunities and threats to the popularisation of this type of solutions in the environmental aspect of sustainable construction. Using the DEMATEL method, these factors were subjected to a cause-effect analysis in order to determine their nature and strength of influence. Through these analyses, the authors identified the key factors influencing the development of substitute solutions complying with the principles of SD and CC at each stage of the life cycle of a building.

2. Analysis of substitution possibilities for the implementation of sustainable construction

Sustainable development policy has now become the dominant environmental and socio-economic trend [10]. In environmental terms, construction is one of the key industries that has a real impact on environmental change and the exploitation of non-renewable natural resources. Unfortunately this influence has mainly negative effects. This is due to the implementation, with respect to the environment, of a long-standing expansion policy without real limitations and standards. Currently, a change in the approach to natural resources is observed. Not only from the social point of view [10–12] but first of all from the systemic point of view: State and European legislation [13], Strategic Implementation Plan (SIP) for the European Innovation Partnership on Raw Materials (EIP RM) [14], Sustainable Development Goals (SDGs) [6], ways Reduced carbon footprints of buildings [15]. Innovative solutions for urban centres such as Cittaslow [16] or *Smart Cities* [12], which, in addition to technical solutions, have the effect of raising residents' awareness of sustainable development [17]. Solutions are being developed to extend the life of raw minerals and thus their useful life [18]. Solutions are introduced to reuse resources, recycle [19], use of waste for further production [20], and circular policy of the use of building materials [21]. An important aspect of sustainability in construction is dedicated solutions for businesses. Manufacturing companies in the construction sector that produce cement, steel and aluminium generate 13% of global carbon dioxide emissions [22]. Management systems are being introduced that promote sustainability like CSR (corporate social responsibility) [23] or specify how carbon emissions can be reduced [5]. There is also a growing field of research into the possibility of changing the chemical composition of cements - the production of CNC (carbon negative cement) alternative cements to reduce the negative impact of cement production on the environment [24].

A phenomenon which positively influences the idea of sustainable development in the construction industry is the substitution on the example of mineral resource substitution [18] or using recycled aggregate as a substitute in concrete production [25]. The phenomenon of replacing "something" with "something" in construction has a very wide range of applications. It may refer to technological solutions, construction products or the manner of performing construction works: reconsumption of building materials [26], effect of substitution of cementitious composites components [27], substitution of building products at the stage of use of the object [28].

Substitution, i.e. interchangeability, can also be applied not only to the choice of products, construction technology or work organization, but also in the manufacturing processes of a product, including the choice of its ingredients/components. In this way, it is possible to achieve better product performance with a positive impact on the environment, such as increased product durability [29] or by using waste materials, e.g. rubber, in the production of compounds [30].

Since the First Earth Summit in Rio de Janerio, however, the concept of sustainable development has been studied and implemented. The principles of caring for the environment defined there also apply to the construction industry. The main idea is to reduce the negative impact of construction production on the environment. The result of this research work are published guidelines, guides indicating how to implement the principles of SC and CC. One of the first publications, which divided building materials used in construction of buildings into 4 groups from preferred to not recommended [31]. The world literature already contains comprehensive studies discussing so-called green contracts through the selection of appropriate materials and products for construction, building installations, etc. [32]. The problem is the dissemination of this idea, among participants in the investment process and decision makers. In the paper [33] the authors try to answer numerous questions such as: "do manuals and guidelines influence the use of alternative materials" coming to interesting conclusions.

More and more intensively and successfully, raw materials and products are being produced and used with waste, reuse or recycling. And this aspect is also highlighted in this work.

One example of substitution in road construction and geotechnics is the replacement of concrete and reinforced concrete elements, whose production has a high carbon footprint, with geosynthetics: Geosynthetics as an alternative to retaining reinforced concrete structures [34], reducing embedded carbon emissions [35]. Apart from the benefit, which directly results from the substitution of construction products, in the given example the transport of earth masses excavated within the construction site, which are used in structures for stabilization of geosynthetics, is also reduced. It is worth mentioning that in Poland, excavated soil is treated as waste if it leaves the construction site [36]. Reducing the use of reinforced concrete elements, incorporating on-site excavated earth and minimising transport are the main arguments for using substitution to reduce the negative environmental impact of construction. However, it is important that substitution in the construction process is treated systemically. Designers specifying certain design solutions should promote sustainable construction, e.g. by taking into account the possibility of substitution of the proposed products with their possible substitutes which can be obtained in the nearest vicinity of the planned investment. In the case of projects involving the demolition of existing infrastructure, however, it is necessary to envisage the maximum use of products obtained in this way: economical waste management [37], recycling in North West Europa [38] or at least to propose other solutions which, after assessment of the recycled material, could be used as substitutes.

Designers will not introduce such solutions if Investors are not interested in them. It is the Investor, as the entity financing the investment, who can impose the necessity of using recycled building products on the design team and who decides whether these products will eventually be used. However, there is a concern about the quality of such products. In addition, the cost of obtaining a substitute from demolition can often be higher than the purchase of a new, full-value product – which is currently the biggest disadvantage of using environmentally friendly substitution solutions. Furthermore, the recovery process can be time-consuming and is associated with the need to convince employees to treat demolition work differently. The habits that are deeply rooted in the culture of construction work impose an approach to demolition as the destruction of buildings, usually by means of heavy equipment or possibly methods using explosives. Only several years ago, acquiring material from demolition was associated exclusively with rubble for paving technological roads on the construction site. Unfortunately, while concrete rubble after removal of reinforcing steel is a good material for sub-base or reuse as aggregate in concrete mix: concrete recycling (RC) and its effect on concrete properties [39]; RC allowed under certain operating conditions [40]. Ceramic rubble without mixing with other material is not applicable in sub-base layers due to its high absorbency and rapid degradation. It may be used for the re-manufacture of small-scale components under certain conditions [41]. While the re-use of brick rubble is problematic, bricks obtained from demolition have already been a sought-after construction product for several years [42]. Recovered bricks are used both for new walls and for the finishing layers of vertical partitions by first cutting them into narrow tiles.

In the case of wood waste from the demolition process, it is most often used as a substitute for recycled components in the production of various assortments, e.g. panels [43]. Increasingly, however, timber from disassembly is also in demand. Trusses and planks from barns or other livestock buildings are used to make bespoke furniture or are incorporated as decorative elements that have no structural function.

However, there are no systemic solutions that would allow the flexible use of demolition elements as substitutes for already customary solutions. A challenging task is to define a general way of verifying construction products obtained from demolition. Often wall elements which had northern exposure are in worse condition than those from a wall exposed to the south. Insolation, the way the wall surface is protected and possible damages to the guttering may lead to a situation where from one object we obtain a varied range of wall products of different quality. Materials obtained in this way cannot be conclusively determined by laboratory testing on the basis of samples in the manner in which newly manufactured products are tested. It is difficult to determine a representative number of samples that should be subjected to such tests.

The use of substitution in the environmental aspect of sustainable construction cannot be equated only with recycled building products. There is a very wide range of construction products that can act as substitutes for traditional solutions and have been manufactured with respect for the environment. Examples include structural elements such as autoclaved cellular concrete (ACC), structural timber, but also building finishes, which are used interchangeably and the production of which makes it possible to minimize or reduce carbon dioxide emissions into the atmosphere. An important factor that will have a positive impact on the environment is the substitution of technology, which will reduce the number of construction processes carried out.

Once again, attention should be paid to the importance of decisions made by designers and the awareness of investors as regards the application of SC in the investment and construction process. The factor negatively influencing the investors' approach to a more environmental approach may be costs. At present, construction production is undergoing a kind of eco-transformation. This is mainly due to EU regulations imposing certain solutions and requirements for construction which, as a consequence, are supposed to have a positive impact on the environment. Traditional solutions are currently cheaper than eco-building, but lack a promising future. Reducing the number of finishing operations in the construction industry will simplify construction technologies, which will automatically reduce the negative impact of construction on the natural environment; what is important, this reduction will occur not only at the stage of construction and operation, but also during future demolition. Less technologically complex building will result in less waste during deconstruction or reconstruction connected with change of use. This will facilitate the circulation policy for construction products. A good practice for convincing clients in the construction industry how a building can be constructed to reduce its negative impact on the environment, and then used with similar respect for the environment, is to present buildings that have already been completed in the above concept. These examples should be proposed by architects who are competent to do so, who have the right skills and opportunities to show that it is possible to build in an interesting way while respecting the environment.

3. Definition and analysis of the determinants of substitution

The analysis of the literature on the subject and observations of construction practice during the design and implementation of construction projects made it possible to define the conditions and factors influencing the use of substitution, including the environmental aspect of sustainable construction. A SWOT matrix was developed (Table 1), which includes factors that constitute the strengths and weaknesses of substitution as well as opportunities and threats in its application. A great advantage of substitution is the possibility to undertake actions reducing the negative impact of the construction industry on the environment. Therefore, the authors set out the characteristics of substitution, which determine the use of substitution precisely because of the environmental aspect of sustainable construction.

Table 1. SWOT matrix on the use of substitution for the environmental aspect of sustainable construction

	POSITIVE	NEGATIVE
	STRENGHTS	WEAKNESSES
INSIDE	1.1. Allows flexibility in construction implementation 1.2. Applicable at any stage of the project 1.3. Accelerates construction work 1.4. Shortens supply chains 1.5. Reduces long distance transport 1.6. Supports local entrepreneurs 1.7. Reduces waste 1.8. Reduces emissions of harmful substances to water, land and air, 1.9 1.9. Reduces use of non-renewable resources 1.10. Reduces carbon footprint	2.1. Lack of experience of designers with the use of substitution of recycled products 2.2. Lack of managers experienced in the use of substitution 2.3. Lack of technological implementation studies (instructions, catalogues. . .) 2.4. Lack of approvals and certificates 2.5. Lack of experienced manual workers 2.6. Lack of knowledge about the durability of recycled materials 2.7. Locally increases negative impact of waste processing
	OPPORTUNITIES	THREATS
OUTSIDE	3.1. Legal acceptance of recycled construction products 3.2. Implementation of the circular economy concept in legislation 3.3. Statutory requirement to use recycled building materials 3.4. Strengthen legislation to reduce carbon footprint 3.5. Establish cooperation with local entrepreneurs (resources, transport, production) 3.6. Certification of sustainable buildings	4.1. Investors' concerns about recycling, 4.2. Legal restrictions on the use of recycled products, 4.3. Legislative problems – lobbying 4.4. Strong position of producers of traditional products on the construction market 4.5. Opposition of the extractive sector 4.6. Lack of adequate education system for staff and society

The analysis of the matrix, in particular the comparison of factors from different fields of the matrix between each other gives the possibility to determine the type of possible general strategy in the substitution activity. On the basis of the factors presented in the SWOT matrix, conclusions can be drawn with regard to the great opportunities for popularising the use of substitution in construction as a pro-environmental solution. Undoubtedly, in the situation of new technological possibilities and more and more diversified offer of the producer market, substitution allows flexible and quick adaptation of the Investors' activities to the dynamics of ecological changes and increasing requirements in this respect. The benefits of substitution are clearly predominant, but comprehensive studies on its implementation are still lacking. Of the six threats presented, two factors relate to legal restrictions, which are constantly being modified due to Europe's environmental policy. The last, sixth factor in the group of threats, is related to the possession of appropriate competences, and it requires the support of the educational system.

DEMATEL was used to identify the causal relationships between the determined factors/characteristics of substitution. The identification of the cause-effect chain will allow identifying the factors that have the greatest influence in the process of substitution application as an action aimed at supporting one of the main aspects of sustainable construction – the environmental aspect.

4. Research methodology

To identify cause–effect relationships in the issue of possible substitution of material solutions of buildings the authors propose to use the DEMATEL method [28, 44–47].

The computational flow is as follows:

1. Determining a set of influence factors, in the proposed study based on SWOT matrix (Fig. 2);
2. Development of a direct influence graph, according to the DEMATEL method, which allows to express the targeted influence of the considered factors on each other, in a cause-and-effect context. A scale with a parameter value of $N = 3$ (where: 0 – no influence, 1 – weak influence, 2 – influence, 3 – strong influence) was used to assess the "strength" of the influence of each factor. The values of the direct influence relations within each pair of factors were determined based on the evaluations of the expert group and they were calculated using fuzzy logic;
3. Based on the relationships determined with the graph, a matrix of direct mutual influence of factors on each other A_D was created;
4. Determination of the normalized direct influence matrix A'_D, which contains all parameters that take values that are in the range $[0, 1]$. The normalizing number (n) is taken as the largest of the sum of the rows or columns of the matrix A_D:

$$A'_D = \frac{A_D}{n} \tag{4.1}$$

$$s^+ = \sum_{j=1}^{n} t_{ij} + \sum_{j=1}^{n} t_{ji} = R_{T_i} + C_{T_i} \tag{4.2}$$

5. It is also possible to develop an indirect impact matrix ΔT:

$$\Delta T = A'^2_D \cdot \left(I - A'_D\right) \tag{4.3}$$

6. Determination of the total influence matrix T:

$$T = A'_D \cdot \left(I - A'_D\right) \tag{4.4}$$

7. On the basis of the above matrices, the determination of the indices of position and relationship, respectively, which express in turn: s^+ – tells about the role of a given factor in the process of determining the structure of links between objects, while s^- – expresses the total influence of a given factor on the others.
   These values are determined according to the formulas (Table 2):

$$s^+ = \sum_{j=1}^{n} t_{ij} + \sum_{j=1}^{n} t_{ji} = R_{T_i} + C_{T_i} \tag{4.5}$$

$$s^- = \sum_{j=1}^{n} t_{ij} - \sum_{j=1}^{n} t_{ji} = R_{T_i} - C_{T_i} \tag{4.6}$$

   When these values are plotted on a graphical representation, it is easy to see which factors have the greatest influence on the others and to determine which are the causes and which are the effects of the actions taken (Fig. 2).
8. Finally, the net impact value is also determined, which tells the factor that has the greatest impact on the others considering both the causal and effect nature (Table 2):

$$\text{netto} = s^+ + s^- \tag{4.7}$$

5. Analysis of research results and conclusions

5.1. Calculations

In order to support the decision on substitution as an activity affecting the environment, the factors listed in the SWOT matrix were taken into account in the study of cause-effect relations. To simplify the recording of the factors in the further analysis by means of the DEMATEL method, the same numbering was left in the division into 4 groups of the SWOT matrix (see Table 1).

For the analysed issue, the form of direct influence graph is presented in Fig. 1. The intensity of relations was coded with the use of differentiated hatching of arc lines.

Based on the graph shown in Fig. 1, a direct influence matrix was created, a fragment of which is shown in Fig. 2.

Next, the values of the matrix elements were normalised according to formula (4.1) and then the relational relations between the analysed factors were calculated according to formulas (4.3)–(4.7). Finally, in accordance with step 7, the values were compiled to build an illustration of the cause-and-effect nature of the phenomenon under study (Table 2).

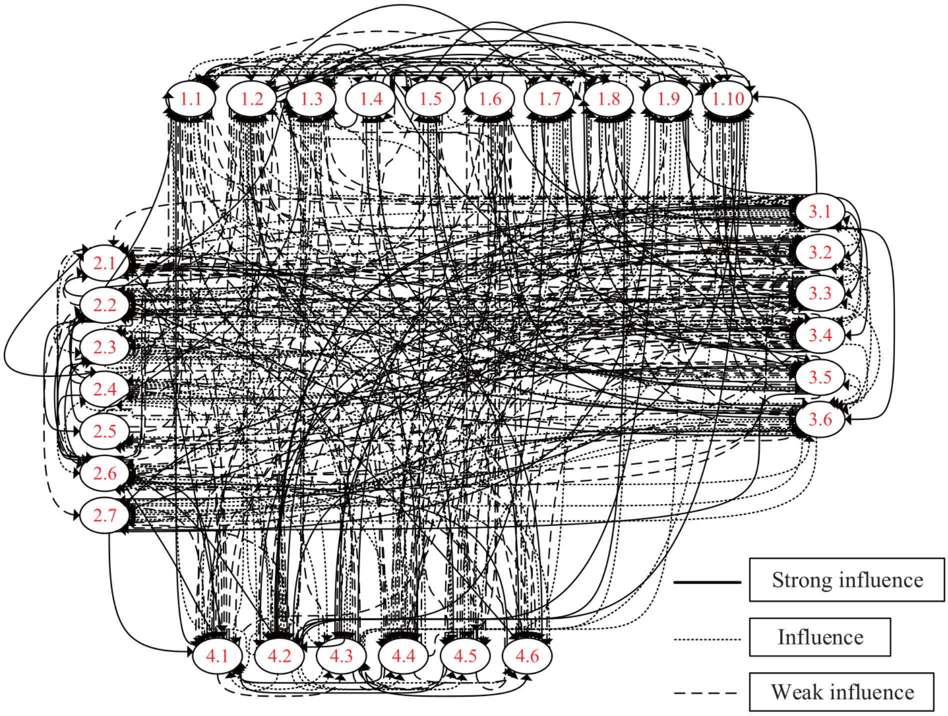

Fig. 1. Direct influence graph – expert evaluation results

$$A_D = \begin{bmatrix} 0 & 3 & 2 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & \dots \\ 2 & 0 & 2 & 2 & 1 & 2 & 3 & 3 & 3 & 3 & \dots \\ 3 & 1 & 0 & 1 & 1 & 0 & 2 & 2 & 0 & 2 & \dots \\ 2 & 0 & 3 & 0 & 3 & 3 & 1 & 3 & 1 & 3 & \dots \\ 2 & 1 & 0 & 3 & 0 & 0 & 2 & 3 & 0 & 3 & \dots \\ 1 & 0 & 1 & 2 & 3 & 0 & 0 & 1 & 0 & 1 & \dots \\ 1 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 2 & 2 & \dots \\ 1 & 0 & 1 & 0 & 0 & 0 & 1 & 2 & 0 & 2 & \dots \\ 1 & 0 & 1 & 0 & 0 & 0 & 1 & 2 & 0 & 2 & \dots \\ 1 & 0 & 1 & 0 & 0 & 0 & 1 & 2 & 0 & 2 & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \end{bmatrix}$$

Fig. 2. Direct influence matrix of the substitution phenomenon under study as an activity influencing the environmental aspect of SC

Table 2. Summary of DEMATEL analysis results

Criterion i	R_{T_i}	C_{T_i}	s^+	s^-	netto
1.1	0.1324	0.3281	0.4605	–0.1957	0.2648
1.2	0.4905	0.2726	0.7630	0.2179	0.9809
1.3	0.2266	0.3885	0.6150	–0.1619	0.4531
1.4	0.3438	0.1997	0.5434	0.1441	0.6875
1.5	0.2704	0.1923	0.4627	0.0781	0.5408
1.6	0.1910	0.2483	0.4392	–0.0573	0.3819
1.7	0.1484	0.4084	0.5569	–0.2600	0.2969
1.8	0.1484	0.4852	0.6337	–0.3368	0.2969
1.9	0.1484	0.3555	0.5039	–0.2070	0.2969
1.10	0.1484	0.4974	0.6458	–0.3490	0.2969
2.1	0.1623	0.3485	0.5109	–0.1862	0.3247
2.2	0.4909	0.3568	0.8477	0.1341	0.9818
2.3	0.4883	0.1345	0.6228	0.3537	0.9766
2.4	0.4883	0.0872	0.5755	0.4010	0.9766
2.5	0.1615	0.1068	0.2682	0.0547	0.3229
2.6	0.1176	0.3333	0.4510	–0.2157	0.2352
3.1	0.2947	0.1419	0.4366	0.1528	0.5894
3.2	0.2001	0.2565	0.4566	–0.0564	0.4002
3.3	0.4089	0.2365	0.6454	0.1723	0.8177
3.4	0.4089	0.2365	0.6454	0.1723	0.8177
3.5	0.1224	0.2635	0.3859	–0.1411	0.2448
3.6	0.2691	0.2322	0.5013	0.0369	0.5382
4.1	0.3420	0.3385	0.6806	0.0035	0.6840
4.2	0.2105	0.3581	0.5686	–0.1476	0.4210
4.3	0.5399	0.1727	0.7127	0.3672	1,0799
4.4	0.3880	0.2274	0.6155	0.1606	0.7760
4.5	0.2118	0.2613	0.4731	–0.0495	0.4236
4.6	0.2118	0.2096	0.4214	0.0022	0.4236

The extreme values of the results of the analysis have been marked in colours,
– yellow for the highest values
– orange the smallest values obtained by individual factors

5.2. Results and their analysis

The analysis was carried out through the use of summative, linear aggregation of the values of position and relationship indicators (s^+ and s^-). The calculations in general are expressed in the graph presented in Fig. 3, which shows the values of the position and relationship indicators.

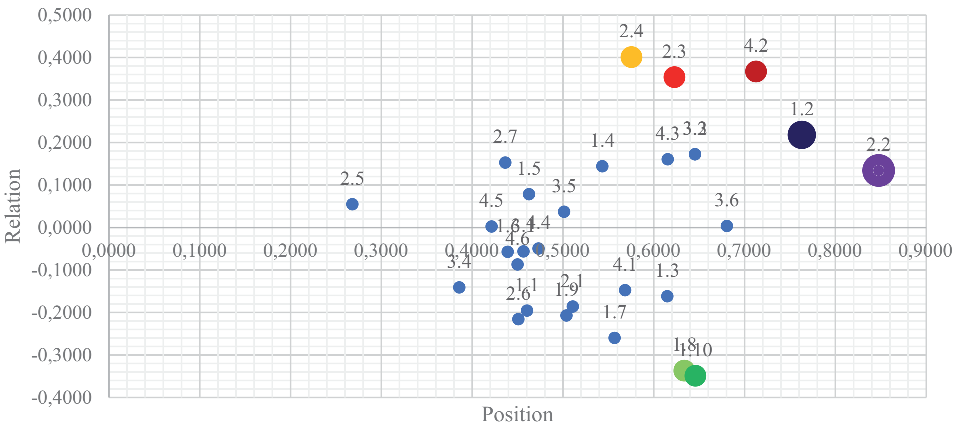

Fig. 3. Graphical interpretation of DEMATEL results

Based on the aggregated values of the item index, it was found that the following factors play the greatest role in determining the nature of the factors: 2.2 (Lack of managers experienced in the use of substitution), 1.2 (Use at any stage of investment) and 4.2 (Legal restrictions to use recycled products). Slightly smaller, but still high impact factors are also shown by: 3.6 (Certification of sustainable buildings), 1.10 (Reduction of carbon footprint), 1.8 (Reduces emissions of harmful substances into water, ground and air), 3.2 (Implementation of the circular economy concept into legislation) and 3.3 (Statutory requirement to use recycled building materials), and 2.3 (Lack of technological implementation studies (instructions, catalogues. . .)), 4.3 (Legislative problems – lobbying) and 1.3 (Speeding up construction works). These factors belong to different groups of the SWOT matrix created earlier, which indicates a strong influence of both opportunities and threats brought about by the implementation of substitution. The distribution of the factors on the item axis also indicates many interrelationships between factors both in the same group and between them.

On the other hand, when analysing the relationship axis, the highest positive values of this indicator achieved and indicating a clearly **causal** character are factors 2.4 (Lack of approvals and certificates), 4.2 (Legal restrictions to the use of recycled products) and 2.3 (Lack of technological implementation studies (instructions, catalogues. . .)).

Almost half of the analysed factors show a negative value of the relationship indicator, hence they should be treated as possible **effects**. Out of the factors with a negative value of the relationship index, a significantly negative value was obtained by 1.10 (Reduction of carbon footprint) and 1.8 (Reduces emission of harmful substances to water, soil and air,), which is a great asset for the pro-environmental effects of substitution. These factors indicate a visible reduction in the negative impacts of construction activities, which should also send a very strong message to legislators.

Factors with a positive sign but close to zero can be treated as elements of a mixed nature, partly causal, partly effectual, but both as causes and effects of much lesser importance.

Both the strong influence on the others and the strong causal character are shown by factors 4.2 (Legal restrictions to the use of recycled products), 2.3 (Lack of technological implementation studies (manuals, catalogues. . .)) and 2.4 (Lack of approvals and certificates), while the strong influence of an effectual character is mainly shown by 1.10 (Reduces carbon footprint) and 1.8 (Reduces emissions of harmful substances to water, land and air,). Unfortunately, in the case of factors that have an effect and at the same time have a strong influence on the others, this group includes factors with a negative resonance, which threaten the implementation and popularization of the use of substitution. These factors are mainly related to the lack of legal regulations and clear elaborations that would allow the participants of a construction project to apply substitution. Taking into account the many advantages of substitution, especially its pro-environmental features discussed in the article, it is worth striving for the creation of clear guidelines for its implementation.

6. Summary

Sustainable construction should become a standard in construction projects. Solutions allowing for the introduction of a circular policy, a standard for buildings to be environmentally certified and unrestricted substitution across the construction spectrum should become a reality. In order for the revolution, the prelude to which is now taking place, to come about, systemic and world-view solutions are required. In the construction industry, this applies to all participants in the investment and construction process. Legislation is needed to guide companies on a course of action that allows, or even mandates, the introduction of comprehensive sustainable development and thus sustainable construction.

In article, the factors related to the application of the substitution phenomenon with regard to the environmental aspect of sustainable construction are summarised. On the basis of the results of the research carried out, cause-and-effect relationships were established between the factors determining the development of the application of substitution in the realization of construction objects, in relation to various activities in the investment-construction cycle.. The conducted analyses indicated the occurrence of strong relationships between the analysed factors from the four groups distinguished in the SWOT matrix. According to the applied DEMATEL method, the greatest role in determining the causal or effect nature of the analysed characteristics was played by the influence:

- 2.2 – Lack of managers experienced in the use of substitution,
- 1.2 – Use at any stage of investment,
- 4.2 – Legal restrictions to the use of recycled products.

On the other hand, the highest positive values of the index on the axis of relations, indicating a clearly causal character, have factors:

– 2.4 – Lack of approvals and certificates,
– 4.2 – Legal restrictions to use recycled products,
– 2.3 – Lack of technological implementation studies (instructions, catalogues. . .).

The dominant, negative value of the relationship index, i.e. potential effects, was obtained by the following factors:

– 1.10 – Reduces carbon footprint,
– 1.8 – Reduces emissions of harmful substances to water, land and air.

The factors mentioned above are key: 1 group in limiting the development of substitution, 2 group is a positive development in the use of substitution, and a reason to develop it Factors of an casual nature and at the same time a strong influence on the others threaten the implementation and popularisation of the use of substitution. These factors are mainly related to the lack of legal regulations and clear elaborations that would allow the participants of a construction project to use substitution. One of the main objectives of this paper is to highlight the pro-environmental aspect of substitution for which clear guidelines for its implementation should be established.

Particularly noteworthy is the result showing that the use of substitution leads to a reduction in the carbon footprint, in particular of recycled products. The impact on the reduction of emissions of carbon gases in the construction industry, which contributes almost 40% of global greenhouse gas emissions (nearly 20 billion tons of CO2 in 2020), is highly desirable.

Assumed by the EU, decarbonisation is already resulting in implementation guidelines by e.g. making carbon footprint calculation mandatory for buildings from 2027. This means that not only new legislation but also a full calculation methodology and carbon footprint database for all building materials will have to be created within the next five years [48].

With regard to the current geopolitical situation in the world, but mainly in Europe, one can foresee far-reaching negative consequences for the construction sector in the years to come. Galloping inflation, disrupted supply chains and regional problems in the supply of hydrocarbons, seen through the prism of sustainable construction, pose major challenges for the construction industry. Green building plans and strategies written into European treaties and national legislation are currently becoming unfeasible, postponed without a specific date of introduction. There is the prospect of a return to energy produced from coal. The consequences for the investment process may be disastrous in the long term because of the SC. The carbon footprint, which is one of the indicators of the negative impact of construction on the environment, may start to increase again. Therefore, more attention should be devoted to the development of regulations on the use of substitution in the construction industry in general. Substitute construction products can provide the end-user with a good technical function and the suppliers with the possibility to limit the increase of the carbon footprint during the production phase. With the guarantee of an adequate quality of construction products, a better view of the supplier's needs, openness to the development of construction production, the use of the life cycle perspective of the construction product in practice and legislative favoritism related to substitution, it will be possible to maintain a pro-environmental development of construction.

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