Influence of Material Composition of Structures on the Accuracy of Flood Loss Evaluation

M Tuscher¹, O Přibýl² and T Hanák¹

¹ Institute of Structural Economics and Management, Faculty of Civil Engineering, Brno University of Technology, Veveří 95, 602 00, Czech Republic
² Institute of Mathematics and Descriptive Geometry, Faculty of Civil Engineering, Brno University of Technology, Veveří 95, 602 00, Czech Republic
tuscher.m@fce.vutbr.cz

Abstract. This paper focuses on the evaluation of flood losses in buildings using genetic algorithms. Specifically, the paper aims to evaluate the influence of material structure and, consequently, different prices on the accuracy of evaluation, taking into account the size of rooms, i.e. the length and width, shape, width-to-length ratio, and flooding depth. The calculation considered three variants of the floor covering solution: laminated composite covering, PVC covering and carpet covering. The results show that the genetic algorithm methodology under development can be used for various materials and compositions, given adequate inclusion of an itemised budget in the data set. The achieved accuracy of evaluation with deviations of <-1 %; 1.72 %> meets the needs of e.g. settlement of insurance claims.

1. Introduction
Evaluation of losses caused to buildings by flooding in terms of the insurance industry raises two basic requirements: to achieve sufficient accuracy of evaluation for the purposes of payment of insurance indemnity while ensuring the entire process of settlement of insurance claims is as fast as possible in order to enable faster repairs of the damaged property, as well as reduce the costs of the process. Insurance companies typically use methods that are not based on creating a detailed itemised budget, but rather use methods such as loss curves. This enables relatively fast estimation of the amount of loss, but the time saved comes at the expense of accuracy.

The aim of this paper is to further elaborate the methodology of evaluation of flood damage to non-bearing structures of the interior of a building. Specifically, this paper expands on the use of genetic algorithm utilised to calculate the amount of damage/loss by including a variant solution of the material composition of structures damaged by flooding.

The paper is structured as follows: firstly, it offer a brief review of available literature followed by outlining the research methodology; a case study is then presented with discussion of results. The conclusion indicates the research limitations and outlines the direction of future research.

2. Literature review
The research presented in this paper emphasises two main issues: the relation between the building’s geometry and the amount of damage, and the aspect of the materials used.

The current body of knowledge includes published works dealing with the relation between building geometry and various aspects. A number of researchers have addressed optimising building geometry to achieve energy efficiency [1–2], where Toleikyte et al. [3] utilise cost curves. The
referenced articles accentuate the relation between building geometry and costs, specifically the building life cycle costs. Generally speaking, building geometry significantly influences the costs as they depend on the dimensions, shape and complexity of a structure [4]. For example, the authors of [5] determined the best building shape in relation to the costs of constructing the walls and foundations (square), and to the layout of the inside of the building (rectangle). Other works dealt e.g. with the relation between building geometry and canyon air flow [6], wind loads [7] or embodied energy [8].

As regards the material, the choice of a certain material affects not only construction costs but also the operation of the resulting structure. The results presented by Frimpong [9] demonstrate that cost overruns in building projects may also be caused by escalation of material prices. In this regard, it is relevant to note that inaccuracy in cost estimation is often related with variability of subcontractors’ prices [10]. As there usually are more suitable variants, it is necessary to compare them taking into account various parameters. This is shown e.g. on the example of façades [11], where costs, frost resistance, the possibilities of maintenance, warranty period and assembly time per square metre are proposed for multi-criteria analysis. This is even though the material costs fall under direct costs in the calculation formula [12] and usually make up the most significant item in the budget. It is important to be aware of the fact that material is among the main quantities based on which buildings are evaluated in terms of energy efficiency and environmental criteria [13].

The extent of flood damage is dependent on a whole range of variables. Korytárová and Hromádka focused on the depth of flooding and the bearing capacity of the underbed [14], hydrostatic, hydrodynamic, erosion, buoyancy, debris or non-physical actions [15]. One should also take into account the type of flood (e.g. river flooding, lake flooding, etc.) as the impact might differ, as presented e.g. for lake flooding [16]. Since research presented in this paper is limited to interior losses that do not influence the statics of a building, most of the aforementioned factors can be omitted.

3. Methodology
As the literature review demonstrated, the influence of building geometry on the related construction costs, the methodology for evaluating flood damage to the interior of a building is based on an analysis of how the area of the rooms and their side (width-to-length) ratio influence the amount of unit loss in CZK/m². The amount of unit loss in relation to the room side ratio and room area for a model depth of flooding of 1 m was mapped in [17] by means of processing 422 variant situations. The results demonstrated that the closer the side ratio gets to 1, the lower the unit loss, and vice versa: the larger the difference between the length and the width of the room, the higher the value of the unit loss. This dependence remains valid regardless of the size of the room. Further inquiry revealed that a growing size of the room and the depth of flooding increased the difference between the results achieved (i.e. inaccuracy) and the budgetary assessment of damage (bill of costs). Over the course of the research, two shortcomings of the older model were revealed: an inaccuracy of estimations and a large deviation between theoretical and empirical values. Another important shortcoming consisted in the fact that the depth of flooding was not used as a variable in the estimation of loss, although it was available in our data set.

Utilising graphic data analysis, we formulated equation (1), which expresses the dependence between quantity \( L \) (loss per m²) and the room area \( X \), the room side ratio \( Y \), and a new variable \( Z \), i.e. the depth of flooding of the room, where all 13 parameters of the equation \( C, A_i, B_i, \alpha_i, a_i, \beta_i \) (where \( i = 1, 2, 3 \)) must be determined so as to make sure that the theoretical model corresponds as much as possible to empirical data obtained by creating the itemised budget. The model parameters were set so as to make sure that the Euclidean distance of the loss values in the model from actual empirical values was as small as possible:

\[
\sum_{i=1}^{N} \left( C \times \frac{(X_i^{\alpha_i} + A_{i1}) \times (Y_i^{\beta_i} + A_{i2}) \times (Z_i^{\gamma_i} + A_{i3})}{(X_i^{\alpha_i} + B_{i1}) \times (Y_i^{\beta_i} + B_{i2}) \times (Z_i^{\gamma_i} + B_{i3})} - L_i \right)^2 \rightarrow \text{min}
\]

(1)

The above was followed by making the loss equation more accurate using genetic algorithms that enabled to dynamically respond to changing material and labour costs over the years. The procedure of
setting up the algorithm is described in more detail in [18], where the range of deviations reached the values of <\(-1\%; 2\%\)> in contrast to previous values of <\(-64\%, 65\%\)>.

The first room model for simulation of various sizes and depths of flooding to determine the basic equation of the genetic algorithm consisted in a room designed using standard materials and structures. For the purposes of the study of influence of materials, three variant solutions (VS) of flooring were defined:

- **VS1**: laminate composite flooring. This included the budgeted costs of work associated with the mounting and removing of laminate floating flooring, baseboards and the bottom counterbalance layer. For the flooding of vertical structures (masonry wall), the budget includes costs of works related to the removal of plaster, high-pressure water cleaning and disinfection of the masonry, manual plastering using lime stucco plaster and final surface treatment using two layers of antimicrobial paint.

- **VS2**: PVC – removal of surface covering and baseboards. This is followed by reassembly of both structures; PVC flooring is glued to the underlay. VS2 includes the same removal and re-application of layers of plaster and paint as in VS1.

- **VS3**: Carpet – removal of surface covering and baseboards. This is followed by reassembly of both structures; the carpet is laid down freely, the carpet is glued only at the seams. VS2 includes the same removal and re-application of layers of plaster and paint as in VS1.

The prices of work and materials were calculated using the KROS budgeting program with 2018 01 price database [19]. The materials used were priced at the standard level. Calculation of costs related to transport of rubble and material on the construction site was made in respect of all works done both on vertical and horizontal structures. All prices for work and material are listed without statutory VAT rate. A diagram of floor layers is shown in Figure 1.

![Diagram of floor layers](image)

**Figure 1.** Diagram of floor layers.

4. Results and discussion
The used budget items and unit prices are indicated in Table 1. Each variant (VS1 to VS3) is characterised by an item code, item description, unit of measurement, and unit price per unit of measurement in CZK.
Table 1. Overview of items used in individual variant solutions.

| Type of floor | Code          | Description                                      | UoM | Unit price |
|---------------|---------------|--------------------------------------------------|-----|------------|
| VS1           | 985111111     | removal of wall plaster                          | m²  | 250.00     |
|               | 985131111     | high-pressure water cleaning                     | m²  | 99.50      |
|               | 612321141     | lime stucco & plaster – manual                   | m²  | 223.00     |
|               | 784331001     | double-layer of antimicrobial paint              | m²  | 47.80      |
|               | 775411810     | disassembly of wooden baseboards                 | m   | 3.15       |
|               | 775541821     | disassembly of floating flooring                 | m²  | 25.20      |
|               | 775591191     | assembly of counterbalance layer                 | m²  | 15.90      |
|               | 611553500     | Mirelon (insulation)                             | m²  | 99.50      |
|               | 775541113     | assembly of floating flooring                    | m²  | 210.00     |
|               | 61152126      | laminate planks                                  | m²  | 558.00     |
|               | 775413315     | assembly of wooden baseboards                    | m   | 47.00      |
|               | 61418151      | baseboard (wood)                                 | m   | 62.10      |
|               | 998775101     | material transport                               | t   | 891.00     |
|               | 997013211     | rubble transport (within constr. site)           | t   | 544.00     |
|               | 998011001     | material transport                               | t   | 233.00     |
| VS2           | 985111111     | removal of wall plaster                          | m²  | 250.00     |
|               | 985131111     | high-pressure water cleaning                     | m²  | 99.50      |
|               | 612321141     | lime stucco & plaster – manual                   | m²  | 223.00     |
|               | 784331001     | double-layer of antimicrobial paint              | m²  | 47.80      |
|               | 776410811     | disassembly of rubber baseboards                 | m   | 11.00      |
|               | 776201811     | disassembly of flooring sheets                   | m²  | 43.90      |
|               | 776121111     | Penetration                                      | m²  | 28.90      |
|               | 776223111     | Welding                                          | m   | 47.30      |
|               | 776221111     | PVC sheets gluing                                | m²  | 120.00     |
|               | 28411000      | PVC                                              | m²  | 510.00     |
|               | 776411111     | assembly of baseboards                           | m   | 113.00     |
|               | 28411009      | PVC baseboard                                    | m   | 55.90      |
|               | 998776101     | material transport                               | t   | 396.00     |
|               | 997013211     | rubble transport (within constr. site)           | t   | 544.00     |
|               | 998011001     | material transport                               | t   | 233.00     |
| VS3           | 985111111     | removal of wall plaster                          | m²  | 250.00     |
|               | 985131111     | high-pressure water cleaning                     | m²  | 99.50      |
|               | 612321141     | lime stucco & plaster – manual                   | m²  | 223.00     |
|               | 784331001     | double-layer of antimicrobial paint              | m²  | 47.80      |
|               | 776410811     | disassembly of rubber baseboards                 | m   | 11.00      |
|               | 776201814     | disassembly of non-fastened flooring            | m²  | 20.90      |
|               | 776212111     | laying down, gluing of seams                     | m²  | 80.10      |
|               | 69751005      | Carpet                                           | m²  | 304.00     |
|               | 776411111     | assembly of baseboards                           | m   | 52.30      |
|               | 69751200      | carpet gripper                                   | m   | 25.10      |
|               | 998776101     | material transport                               | t   | 396.00     |
|               | 997013211     | rubble transport (within constr. site)           | t   | 544.00     |
|               | 998011001     | material transport                               | t   | 233.00     |
We had available $N = 2,800$ instances of loss $L$ for the given values of room area $X$, side ratio $Y$, and depth of flooding $Z$, i.e. altogether 2,800 quadruples $(X_i, Y_i, Z_i, L_i)$ for $i = 1, 2, \ldots, N$ for each variant solution. The results achieved are provided in Table 2.

Table 2. Comparison of the range of deviations for the individual variant solutions.

|                | VS1 (laminate) | VS2 (PVC)   | VS3 (carpet) |
|----------------|----------------|-------------|--------------|
| Number of inputs | 2,800          | 2,800       | 2,800        |
| Zero deviation  | 1,601          | 1,601       | 1,601        |
| Range of deviations | <-1%; 1.72%   | <-1%; 1.72% | <-1%; 1.72% |
| Maximum unit deviation | around 65 CZK | around 65 CZK | around 65 CZK |

The echo check of the algorithm’s calculations proves its accuracy which was achieved by gradual adjustment of individual coefficients and mathematical conditions in modelling of the genetic algorithm itself. The current results are more accurate than originally anticipated. However, this will be hard to maintain in the next step when doors and windows in vertical structures will be included in the calculation. Nevertheless, the current accuracy of the calculations raises a hope that even with the doors and windows included, the range of deviations will not exceed ±10 percent.

Changing materials in the algorithm’s calculations does not affect the results at all. The level of inaccuracy remains the same for VS1, VS2 and VS3. This means that the basic model and methodology of the genetic algorithm is sound and can be used for various materials and compositions, given correct inclusion of an itemised budget in the data set.

Considering that insurance companies are willing to tolerate a deviation of ± 10 %, the deviation interval of <-1%; 1.72%> achieved in the new model is perfectly acceptable, even by a large margin.

5. Conclusion

This paper presents original results of methodology for evaluation of flood losses in buildings using genetic algorithms. The damage was simulated for rooms of various sizes, shapes and depths of flooding, where for the purposes of study of the influence of materials, which was the subject of the previous step in development of the methodology, three variant solutions of flooring (laminate composite flooring, PVC flooring and carpet flooring) were defined. The results achieved demonstrate that using genetic programming yields highly accurate results (accuracy deviation in the range of <-1 %; 1.72 %>) regardless of the materials used in the specific structures and their unit price.

However, this research is not without limitations. Firstly, the study omits other flooding parameters, such as duration of the flooding and water velocity. Secondly, it only considers losses in selected structures, i.e. it does not take into account damage which could impact e.g. the statics of a building. Thirdly, the effect of doors and windows is omitted in this stage of research.

In the following part of the research, it will be necessary to account for the rooms’ doors and windows. However, incorporation of this variable into the genetic algorithm may prove extremely challenging and, consequently, other ways of including doors and windows in the methodology under development will have to be found.

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