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Abstract

Purpose – Integrating the aspects of sustainability into facilities design has become a designers' challenge, and the early design phase is seen as the most important in implementing sustainability into facilities design. Therefore, this paper aims to analyze the factors that influence sustainability assessment of preliminary design of facilities and predicts sustainability assessment depending on those factors.

Design/methodology/approach – Data were collected by survey questionnaire distributed to project managers using a six-point Likert scale. Obtained data were modeled with general regression neural network (GRNN) using DTREG software. In total, 27 factors were chosen for determining the most accurate predictive model, and their importance was computed.

Findings – The six most important factors for sustainability assessment of facilities design are: work experience, work on several outline design proposals, resolving issues between stakeholders, prioritization of participants in the design phase, procurement management and defining projects' program and goals. The predictive model that was used for prediction of the sustainability assessment was shown to be highly accurate, with MAPE (mean absolute percentage error) amounting to 2.58 per cent.

Practical implications – Using the same approach, assessment of every other factor for the preliminary design can be predicted and the factors that are most influential to its sustainability can be obtained.

Originality/value – The paper supports the sustainability improvement of the preliminary design of future facilities' projects, as well as support during the decision-making process.

Keywords Neural network, Assessment, Sustainable design, DTREG software, General regression neural network, Preliminary design

Paper type Research paper

Introduction

In a traditional sense, facilities management (FM) has been regarded as management of activities concerning cleaning, caretaking, repairs and maintenance (Atkin and Brooks, 2009). In Enoma (2005) it is seen as a discipline of planning, designing, constructing and managing space, in every type of building structure with a purpose of enhancing the organization's ability to compete in the market. In the past decade, FM has been gaining more importance, constantly growing as a business and a scientific discipline (Sapri and

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Pitt, 2005). The discipline should have a strategic importance by adding value to the core business delivery of an organization (Aksorn and Charoenngam, 2015).

To enable organizations to be more competitive, FM should coordinate all activities for planning and designing the building, management of buildings and buildings systems and also equipment and furniture (Enoma, 2005). Additionally, real estate and FM should be more focused on the needs of the users and value creation (Temeljotov Salaj *et al.*, 2015). Similarly, Jensen (2010) stated that recently, the main focus of FM is to create added value. Therefore, there is a need to improve the understanding of how FM can add value to the core business (Jensen, 2010).

Teicholz (2001) states that facilities management deals with knowledge from engineering, architecture, design, accounting, finance, management and behavioral science. The FM responsibilities cover real estate, planning, budgeting, space management, interior planning, interior installation, architecture/engineering services and also building maintenance and operations (Bu *et al.*, 2010). The enlisted aspects show the multidisciplinary nature of FM covering issues concerning the benefits of the organization with a goal of achieving efficiency and effectiveness within an optimal cost, quality and time (Enoma, 2005).

Facilities management and sustainability

Construction is seen as an industry with intensive consumption of raw materials and energy (Stoy *et al.*, 2009), significant consequences on human living and also as an industry with a large impact on the environment (Oteiza and Tenorio, 2007; Bakens, 2003; Woolley and Kimmins, 2000). To mitigate the negative impacts, the concept of sustainability is introduced with a goal of fulfilling the needs of the present with respect to the needs of the future [UNWCED (United Nations World Commission on Environment and Development), 1987]. This concept intends to balance the needs and demands of society and the environmental and economic sphere, by establishing the three main sustainability pillars: economic, social and environmental, which are "Triple Bottom Line" – TBL of sustainability (Elkington, 1999).

Incorporating sustainability issues in a business, including facilities construction and their maintenance became an important issue for the whole community. Therefore, it is an increasing global need to incorporate sustainability in FM to include social and environmental issues in addition to economic objectives (Elmualim *et al.*, 2009). It could be said that for traditional FM, sustainability creates an opportunity to become a strategic support function (Aksorn and Charoenngam, 2015).

Incorporating the sustainability issues in FM leads to developing the concept of sustainable facilities management (SFM) (Elmualim *et al.*, 2009). SFM is important not only for core business but also for local and global society. Therefore, SFM will have to replace traditional FM (Aksorn and Charoenngam, 2015).

A list of building sustainability performance indicators (SPIs), including economic, environmental and social, was developed by Kamali and Hewage (2015). The results of the paper indicate that among various environmental performance criteria used in different publications, 16 SPIs are the most significant. In total, 9 SPIs and 12 SPIs are identified as the most commonly used criteria related to the life cycle of economic and social performance of buildings, respectively.

Although SFM is becoming increasingly important for construction firms, there are also obstacles for incorporating sustainability in FM. Construction costs of the sustainable facilities are higher than the costs of the unsustainable ones (Katz, 2003). Additionally, there are perceived barriers such as lack of awareness and knowledge for SFM, and also cost and time (Elmualim *et al.*, 2009). The important barrier for FM implementation is lack of individual and organizational consensus for sustainability focus (Elmualim *et al.*, 2009). For overcoming these barriers, facilities managers can play an important role (Aksorn and Charoenngam, 2015). Also, managers can create organizational culture that is focused on sustainability (Galpin *et al.*, 2015).

Facilities management and sustainability in design phase

The facilities life cycle and particularly facilities design phase is usually seen as a fragmentized process that is poorly planned (Barber *et al.*, 1998), and the design phase is seen as the most important phase of the facilities life cycle. This phase should provide drawings and specifications according to requirements and preferences of the client. Additionally, facility design should be focused on its main objectives such as: sustainability, aesthetics, accessibility, historic preservation, functionality/operability, cost effectiveness, security/safety and productivity (Bu *et al.*, 2010).

The design may affect the internal comfort of the facility, and for the users, the design should offer pleasant and comfortable indoor climate condition (Stoy *et al.*, 2009). Also, the design may affect the facility's sustainability and also facility's longevity or maintenance (Adeyeye *et al.*, 2013). Therefore, it is necessary that the designers place more emphasis on sustainability issues (Chendo, 2013). In facilities design and construction, they should integrate the economic, social and environmental aspects (Rafindadi *et al.*, 2014; Halliday, 2008; Smith and Rootman, 2013).

The decisions made in the design phase influence the facilities construction phase, facilities operation and also the phase of their demolition, so in the early design phase, life-cycle aspect is essential as an input (Temeljotov Salaj *et al.*, 2015).

The early design phase is identified as crucial for facilities sustainability (Bogenstätter, 2000; Crawford, 2013; Eid, 2013; Taylor, 2011; Tharp, 2013; Kamali and Hewage, 2015), and decisions made in this phase are responsible for the biggest part of sustainability characteristics of the project (Graedel *et al.*, 1995). Hence, meeting the sustainability needs in facilities preliminary design has become a designer challenge, although implementing the sustainability concept into facilities design phase increases projects' complexity and it leaves the designers under pressure. Therefore, the role of facilities managers and their involvement in decision-making during the design stage is of crucial importance (Enoma, 2005; Bu *et al.*, 2010). It could lead to adding value to the facility by enabling less "rework" (Enoma, 2005). Additionally, customers can be engaged in a way that is beneficial for them and for the firm (Saarijärvi *et al.*, 2013).

It could be concluded that regarding the project life cycle, the FM has a different scope and activities. Implementation of FM during the early stages of facilities' life cycle can increase the sustainability of the facility, can create greater money value and more satisfied customers, while providing the better facility that is attractive, user-friendly and with effective operation. Hence, FM should be involved in design determination as earlier as possible (Enoma, 2005). Therefore, Andrade *et al.* (2012) proposed two types of key indicators for sustainable construction: core indicators and additional indicators. They proposed core indicators to be used in the conceptual stage, whereas additional indicators to be used only in the next stage, pre-design stage.

Facilities management and sustainability in design phase in the Republic of Macedonia

Jensen (2010) stated that FM should deliver qualitative better services than before to their end users, customers and clients. In the Republic of Macedonia, this need is also recognized. There are many laws that cover the fields relevant for facilities management, but FM and sustainability are still partly covered by the legislative regulations. In fact, the issues of FM are not fully covered with the scope of the effective regulatory acts.

The issues concerning building construction and building maintenance, as well as their sustainability, are, in general, included in the laws regarding construction of facilities, spatial and urban planning, housing, protection of the environment, energy efficiency, etc.

- In the *Law on Construction* (Official Gazette of RM, 2013a), the means of construction are prescribed, the principal building demands, the necessary documentation for obtaining construction permit, rights and obligations of the participants in the construction, means of operation and maintaining the construction, as well as other issues related to the construction.

The principal building demands are related to the mechanical resistance, stability and seismic protection, fire protection, sanitary and health protection, protection of the working and living environment, noise protection, safety during operation, efficient energy use and insulation, unobstructed access to and from the building and technical characteristics of the applied construction materials.

In the *Law on Construction*, different types of projects are mentioned depending on their scope:

- project for preparatory works;
- preliminary design project;
- construction design project;
- project of the constructed facility; and
- project for operation and maintenance.

Depending on the project purpose, the project could be defined as:

- architecture;
- construction (static and seismic);
- electro-technic;
- thermo-technic;
- traffic; and
- other projects depending on the building type.

The projects as described in the *Law on Construction* should comply with rulebooks relevant for project content, standards and design norms and other relevant technical regulations.

The project of facility construction and the project for facility use and maintenance, according to the law regulations, is an obligation of the investor of the project.

With the facility use and maintenance project, the optimal technical–technological and functional conditions are determined that ensure the longevity of the facility in its separate parts and the facility in total. The project for facility use and maintenance is an obligation for facilities classified as Type 1, i.e. facilities of significance for several municipalities or the Republic:

- For designing the facilities, particularly important is the *Rulebook on Standards and Norms for Facilities Designing* (Official Gazette of RM, 2012b), where standards and norms for designing of facilities are prescribed, and they are being applied for project documentation for construction, outbuilding, upgrading and reconstruction of the facilities, for projects revision, supervision and construction of the facilities.

- Other Laws important for FM include the *Law on Housing* (Law on Housing, Official Gazette of RM, 2012a). This Law regulates the housing types, the management of the residential buildings, the manner of management and maintenance of facilities and other issues related to housing.
- In the *Law on Environment* (Official Gazette of RM, 2005), the rights and obligations are determined to enable conditions and fulfill of the right of the citizens for healthy environment. The housing sector does not have a special consideration under this regulatory act.
- *Rulebook on Energy Characteristics of Buildings* (Official Gazette of RM, 2013b) – The energy efficiency of buildings is being highly implemented in the housing sector and is regulated under regulations aligned with EU legislative and directive.
- The *Law on Spatial and Urban Planning* (Official Gazette of RM, 2014) covers the issues related to the urban planning and types of urban plans, and it considers cities' sustainable growth. Facilities are considered as a part of the city.
- The *National Strategy for Sustainable Development of R. Macedonia* (Ministry for Transport and Communications of RM, 2010), gives the present condition of the housing sector and its influence onto the environment. Also, future predictions and directions are given with a goal of implementing European Directive into mitigating negative impacts onto the environment.

In facilities management in the Republic of Macedonia, similarly as stated by Enoma (2005), there is an intention for a more holistic approach, so that early design phase and, also facilities maintenance, to be an integral part of the same firm in their construction package. This approach started to be used in the Republic of Macedonia recently and there is intention for the building furniture and the future facility maintenance to be offered by the same construction firm package with facility construction.

Aim of the paper

In the Republic of Macedonia, facilities have a big impact on the environment and large share of electricity use (State Statistical Office of the Republic of Macedonia, 2013), that could have considerable influence on human living and overall negative impact on sustainability (Shen *et al.*, 2007). This fact points out the significance for further research for improving the sustainability of the facilities in all phases of their life cycle.

Project managers can have a contribution in increasing the sustainability of the facilities design by managing the factors that influence the sustainability of the design. Therefore, the focus of the research of this paper is determining factors that influence the sustainability assessment of facilities preliminary design. A survey was conducted, and from the retrieved data, a model was created to obtain the most important factors which influence the sustainability assessment of facilities preliminary design and to predict facilities design sustainability assessment. The prediction model is based on general regression neural network (GRNN).

Method

General regression neural network

Neural networks (NNs) are mathematical (computational) structures composed of n processors called neurons, which are models of biological neurons. The neurons are interconnected in a network and they learn from experience, which is the main characteristic of the biological neural systems. Of course, the biological neuron is much more complicated than the artificial neuron.

NN is formed by interconnecting many neuron models. The NN can be trained to obtain (approximate) a specific function, by adjusting the values of the components of the vector w, i.e. weighting coefficients between the neurons.

There are many different types of NN architectures for solving different type of problems, and the learning ability of the NN depends on the architecture of the NN and the algorithm applied for training. NN generally contains three layers of neurons: input layer, hidden layer and output layer. But depending on the task which should be solved by the NN, more hidden layers can be added, to obtain more powerful performance of the network (Neural Networks, 2015).

GRNN used in this paper consists of four layers: input, pattern, summation and output layer (Figure 1). The number of input units in the input layer depends on the number of components of the input vector X. One of the most useful characteristic of this GRNN is that it can converge to the desired function of the data with only several training samples available, which makes GRNN useful for applications. The author of this NN, Specht (1991) has demonstrated that sometimes this GRNN requires only 1 per cent of the training samples required by backpropagation NN to achieve comparable accuracy (Specht, 1991) (Figure 1).

In this paper, GRNN is used to model the relationship between the output variable and several input variables from where several important conclusions could be inferred regarding the relationship of the observed variables. Also, by resolving a regression problem, a prediction model has been established.

The computation of the most probable value of Y for each value of X based on a finite number of possible noisy measurements of X and the associated values of Y is called *regression* of a dependent Variable Y from the independent Variable X (Specht, 1991).

At the beginning, the functional form of the dependency of Y from X is not known. GRNN does not require any knowledge about the functional form of this dependency (Parzen, 1962). The GRNN structure learns the relationship between Input X and Output Y directly from the available values of X and Y and after the learning process it immediately starts to generalize and to predict (estimate) the values for Y for any new value of X.

GRNN has been applied by many authors. Yip (2014) applied GRNN for prediction and analysis of construction equipment maintenance costs. Sun *et al.* (2008) used GRNN for predicting diurnal and seasonal gas from some buildings.

Celikoglu (2006) has made application of GRNN for travel mode choice modeling. Cigizoglu and Alp (2005) used GRNN for modeling river sediment yield, and Celikoglu and Cigizoglu (2007) used GRNN for modeling transportation trip flow.

In this paper, for modeling the data, DTREG modeling software is used (Sherrod, 2013b). Several NN models were tested during the modeling process, and the GRNN network has been determined as being the most appropriate. It is suggested to try several NNs when the relationship between the input and output variables is not known in advance and it is not known which NN architecture will be the most suitable for data analysis. For different types of data, different NNs will give best results. The SVM model, multilayer perceptron network, and several other predictive models which are

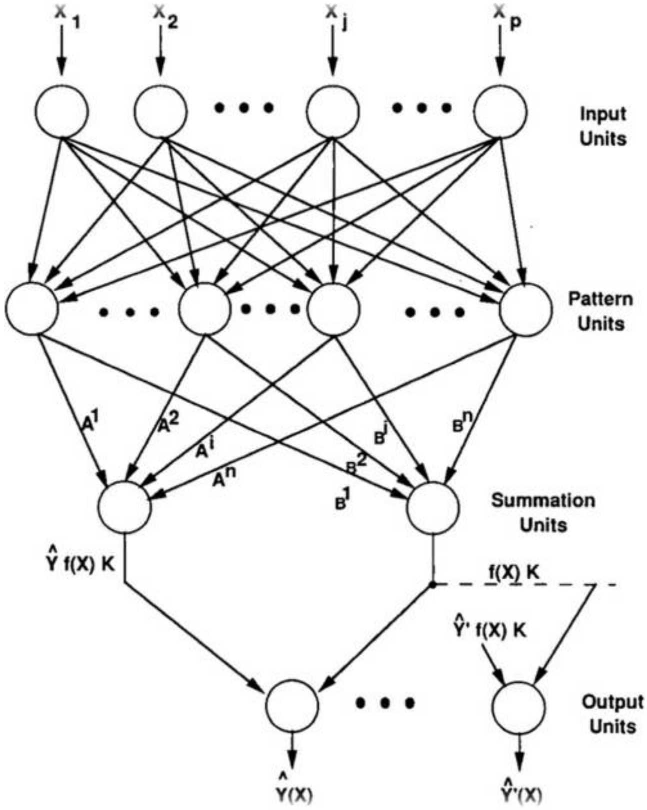

Figure 1.
GRNN architecture

Source: Specht (1991)

available in DTREG were applied for modeling, and the best accuracy has been achieved with the application of the GRNN.

In the DTREG software, GRNN is used by the name "PNN/GRNN". PNN is a shortcut for probabilistic neural network. This is because those two NNs have similar architecture and PNN is used when the target variable is of categorical type, and GRNN is used when the target variable is of continuous type. DTREG uses two types of variables: continuous and categorical. The continuous variable has a numeric value and the relative magnitude of the value is significant. For example, continuous variables are pressure, temperature, height and probability of some event. If a variable is numerical, and although its values are discrete and do not form a continuous scale, it is declared as continuous. The categorical variable has values that function as labels rather than as numbers. Examples can be: gender, marital status, etc. The variable gender can have value 1 for male, 2 for female, where the actual magnitude of the value is not significant. The values 1 and 0 might also work well for this variable. DTREG also allows using non-numeric (character string) values for categorical variables. So, the values for the variable gender could also be: "Male" and "Female" or "M" and "F". Categorical variables are stored and compared as string values. So, as string values for categorical variables, the value 002 is different from 2, but as values for continuous variable, the values 0.002 and 2 are equal (Sherrod, 2013a).

In this paper, the target variable is continuous (it has values from 1 to 6), so DTREG chooses GRNN as a predictive model automatically, according to the type of the target variable.

In comparison with the most popular MLP (multilayer perceptron neural network) PNN and GRNN can be trained faster than MLP network, they are more accurate then MLP, but they are slower then MLP, and they require more memory space than MLP to store the model.

Data collection
An anonymous survey was conducted among 112 project managers in construction firms in the Republic of Macedonia. The goal of the survey was to determine the project managers' opinion about the factors that influence the sustainability assessment of facilities' preliminary design. The survey was conducted by means of a personal handover of the questionnaire in the period of August-November, 2015. Because of this type of interviewing, the response rate is maximal. The respondents had working experience in all life-cycle phases of a facility, such as: design phase, performing works at facilities sites, installment of equipment and furniture in facilities, facilities trial period and exploitation.

Regarding the gender structure of the respondent, 39.3 per cent are female and 60.7 per cent are male. Most of the respondents have working experience in micro enterprises (64.3 per cent), in small (14.3 per cent), in big enterprises (13.4 per cent) and in medium enterprises (8 per cent). This proportion is acceptable considering that in the Republic of Macedonia most of the construction companies (97 per cent) are small firms with up to 50 employees (of which 88 per cent are micro enterprises). Also, the fluctuation of the engineering staff between different companies is significant, meaning that the interviewees have had working experience in companies with different size that enables them to have a broad overview on different aspects of companies organization. Regarding their project work experience, 45 per cent of the respondents have experience in the high-rise sector with project value up to €3m, and 55 per cent in projects with value up to €10m.

Regarding their work experience, 60 per cent of the respondents have more than 10 years of work experience, which validates the survey in terms of realistic conditions in the current project design. According to the interviewees, the micro and small enterprises respect certain aspects of sustainability, especially the social and environmental aspects according to the public regulations. Also, they consider certain economic aspects with a goal to incite economic growth of the company and its endurance on the market. Considering the limited resources with which micro and small enterprises operate, and due to the respect of certain sustainability aspects, the enterprises during project design associate with each other and make mutual procurement offer for project design. Also, they engage consultants or companies for improvement of sustainability implementation in the project design.

The sample structure by type of enterprise, respondents' gender and work tenure is given in Table I.

Survey design and questionnaire
The questionnaire developed by the authors consists of one target question related to the conducting sustainability assessment of the preliminary design. The other questions have been constructed from extensive research on most recent project management and sustainability literature (Othman and Ayman, 2011; Silvius *et al.*, 2012; Gareis *et al.*, 2009;

Eid, 2013; Tharp, 2013), and are seen as potential factors, i.e. predictors, influencing and correlated with the target question.

The participants (project managers) were asked to assess each question/predictor on a six-point Likert scale ranging from 1 – unimportant to 6 – extremely important.

In the primary analysis, the total number of predictors was 72, and after the sensitivity analysis, 27 factors were chosen in the modeling process to receive the most accurate predictive model. From the beginning of the process of modeling all factors that are related to sustainability (from all 72) were tested as predictors, but only 27 of them were chosen as predictors of the model, those which reduced the error of the model (i.e. which contributed for receiving most accurate model), the rest of them which increased the error of the model were removed. In fact, the process of modeling is choosing the most relevant predictors which will contribute for receiving most accurate predicting. Some of the excluded factors are factors related to: defining project budget in the initiating phase; analysis of external factors influencing the project such as economical factor; analysis of legal factor; selection of suppliers regarding sustainability aspects, etc. Some of the questions from the original questionnaire (with 72 questions) are regulated by law, and also some of the 27 questions selected for the model, such as Questions 5, 14, 19, 20, 23, are also regulated by law.

The questions/factors that were chosen as predictors are shown in the Appendix.

Results and discussion

Kamali and Hewage (2015) and Andrade *et al.* (2012) have proposed a list of sustainability performance factors using appropriate literature review. In our paper, using GRNN, a model for the relationship of several important sustainable factors was made, their importance in the model was computed and sustainable assessment was predicted.

The target (dependent) variable in the model is: sustainability assessment of the preliminary design. The DTREG software analysis showed that the mean target value is mean value = 5.214 on a six-point scale; the standard deviation is SD = 0.784; the minimal and maximal values are 3 and 6, respectively.

For every predictor variable, DTREG computes the mean target value for each category of answer for that predictor (Table II gives only eight predictor variables [from the 27] and the mean target values for each category of answer). For example: for Predictor 2 (given in Appendix) working experience, there are five categories of answers: (a) less than 2 years, (b) from 2 to 5 years, (c) from 6 to 10 years, (d) from 11 to 20 years and (e) more than 20 years. For each category of answer (according to questionnaire answers, there are only four different answers – the answer (a) is not answered by the 112 employers) DTREG computes the number of rows (employers) with that category, its percentage from the total number of rows and the mean target value. This report can be used to see for which category the project managers gave either minimal or maximal estimation of the target variable, which is important for the sustainability assessment of the preliminary design of facilities.

For each variable with a numerical value (predictor and target), DTREG computes the minimal, maximal and mean value and its standard deviation (Table III).

Table I. Sample structure by type of enterprise, respondents' gender and work tenure

Type of enterprise/frequency	Gender/(%)	Work tenure/frequency
Micro enterprises/72	Female/39.3	2-5 years/28
Small enterprises/16	Male/60.7	6-10 years/28
Medium enterprises/9		11-20 years/38
Big enterprises/15		More than 20 years/18

Predictors	Target variable/target mean
1	
72 64.29% a	5.1250
16 14.29% b	5.0000
9 8.04% c	5.4444
15 13.39% d	5.7333
2	
28 25.00% b	5.2857
28 25.00% c	5.1786
38 33.93% d	5.0526
18 16.07% e	5.5000
3	
1 0.89% a	6.0000
19 16.96% a, c	5.1579
14 12.50% c	5.2143
78 69.64% e	5.2179
4	
18 16.07% 4	5.2222
56 50.00% 5	5.1250
38 33.93% 6	5.3421
5	
22 19.64% 4	5.1818
43 38.39% 5	5.0930
47 41.96% 6	5.3404
6	
7 6.25% 3	5.2857
21 18.75% 4	5.1429
63 56.25% 5	5.0952
21 18.75% 6	5.6190
7	
14 12.50% 3	4.6429
49 43.75% 4	5.1429
23 20.54% 5	5.3478
26 23.21% 6	5.5385
8	
4 3.57% 3	4.2500
34 30.36% 4	5.0882
32 28.57% 5	5.1563
42 37.50% 6	5.4524

Table II. Eight predictor variables and the mean target values for each of its category values

DTREG also computes the effect of the value of each variable on the quality of the model, and in Table IV from the report from DTREG, the importance of each predictor variable for the target variable in the model is noted.

The six most important variables for this target variable are: (see Table IV): 2 – work experience, then 11 – which is work on several variants of preliminary projects, then14 which is resolving problems among the participants in the project, after it is Variable 13 which is prioritizing of the participants in the project according to their impact in the project, 23 which is procurement management and indicator 5 related with defining of project's

Table III.
Minimal, maximal, mean value and its standard deviation for the variables with numerical value (predictor and target)

Variable #	Rows	Minimum	Maximum	Mean	SD
4	112	4.00000	6.00000	5.17857	0.68419
5	112	4.00000	6.00000	5.22321	0.75249
6	112	3.00000	6.00000	4.87500	0.78062
7	112	3.00000	6.00000	4.54464	0.98097
8	112	3.00000	6.00000	5.00000	0.90633
9	112	3.00000	6.00000	4.97321	1.03906
10	112	3.00000	6.00000	4.92857	1.05825
11	112	2.00000	6.00000	4.77679	1.17039
12	112	2.00000	6.00000	4.10714	1.22005
13	112	2.00000	6.00000	4.39286	1.45380
14	112	3.00000	6.00000	4.92857	0.97938
15	112	4.00000	6.00000	5.41071	0.73865
16	112	3.00000	6.00000	4.61607	0.91852
Target	112	3.00000	6.00000	5.21429	0.78409
17	112	4.00000	6.00000	5.01786	0.68115
18	112	4.00000	6.00000	4.88393	0.85299
19	112	4.00000	6.00000	5.10714	0.81676
20	112	3.00000	6.00000	5.11607	0.71646
21	112	4.00000	6.00000	5.12500	0.89767
22	112	2.00000	6.00000	4.13393	1.13779
23	112	3.00000	6.00000	4.20536	1.02764
24	112	4.00000	6.00000	5.48214	0.56667
25	112	3.00000	6.00000	5.19643	0.61002
26	112	2.00000	6.00000	4.64286	1.00762
27	112	1.00000	5.00000	2.66071	1.08194

program and goals. All these variables can be taken into consideration as priority variables in the designing future preliminary projects.

DTREG software for GRNN predictive modeling has an option for reducing the number of the neurons of the NN to improve the accuracy of the model and its speed. In this model, this option is used and the number of the neurons is reduced from 112 to 77.

After the training phase, when the GRNN is trained and the model is established, GRNN can predict the values of the target variable for new values for the predictors.

From the DTREG's *Validation data row report file*, one can read all predicted values for the actual target variable.

The correlation between the actual and the predicted values of the target variable for the model is 0.92.

The accuracy of the model is estimated from the validation data (Table V). Usual estimators of the accuracy of the model are the *coefficient of determination* R^2, which for this model is $R^2 = 0.84$, and *mean absolute percentage error* (MAPE), which for this model is MAPE = 2.58, which means the percentage error of the model is around 2.58 per cent.

The *coefficient of determination* R^2 indicates how good data points fit the approximation function which is obtained from the model – it is a measure of the global fit of the model. The value $R^2 = 0.84$ can be interpreted as: around 84 per cent of the variation in the response can be explained by the explanatory (predictor) variables. The remaining around 16 per cent can be attributed to unknown variables or inherent variability.

The model has very high accuracy considering that the data are real. Predictive models based on NNs (like GRNN) often give better results in modeling nonlinear relationships, in comparison with other predictive models. For example, Molfenter *et al.* (2011) have developed

Variable	Importance
2	100.000
2	100.000
14	44.216
14	44.216
23	31.960
5	24.524
25	18.681
21	9.593
12	5.023
20	4.804
24	4.455
27	2.243
15	0.979
7	0.415
18	0.373
6	0.304
17	0.263
4	0.164
10	0.139
9	0.122
26	0.121
16	0.072
1	0.024
8	0.013
22	0.003
3	0.000

Table IV. Overall importance of variables

a hybrid conjoint predictive model for predicting the sustainability of organizational change (in health institutions) which is based on OLS regression analysis (ordinary least square or linear regression analysis). For the model, they received R^2 to be 0.77.

Conclusion

Integrating the sustainability issues in facilities design provides benefits for the facility, in terms of economic issues and more environment-friendly facility that better meets the users' needs.

The early design phase is responsible for the biggest part of the decisions regarding sustainability of the facility, so sustainability in early facility design stage become a designers' challenge. Therefore, this study is focused on sustainability factors in facilities preliminary design preparing in the Republic of Macedonia.

The design process of facilities depends on numerous factors, and this paper examines how project managers assess the factors that influence the sustainability assessment of a preliminary design.

In this paper, 27 factors-variables were chosen as factors-independent variables from which the target variable was modeled and predicted, and for which the analysis has shown that are most relevant for the modeling process. From the DTREG software report, using the GRNN predictive model for modeling the data, the six most important factors were obtained:

- work experience;
- work on several outline design proposals;
- resolving issues between stakeholders;

Table V.
Analysis of variance

Training data	Mean target value for input data = 5.2142857
	Mean target value for predicted values = 5.2132044
	Variance in input data = 0.6147959
	Residual (unexplained) variance after model fit = 0.0563397
	Proportion of variance explained by model (R^2) = *0.90836* (*90.836%*)
	Coefficient of variation (CV) = 0.045521
	Normalized mean square error (NMSE) = 0.091640
	Correlation between actual and predicted = 0.953831
	Maximum error = 1.0001256
	RMSE (root mean squared error) = 0.2373599
	MSE (mean squared error) = 0.0563397
	MAE (mean absolute error) = 0.0672312
	MAPE (*mean absolute percentage error*) = *1.2525029*
Validation data	Mean target value for input data = 5.2142857
	Mean target value for predicted values = 5.2203823
	Variance in input data = 0.6147959
	Residual (unexplained) variance after model fit = 0.0982515
	Proportion of variance explained by model (R^2) = *0.84019* (*84.019 %*)
	Coefficient of variation (CV) = 0.060114
	Normalized mean square error (NMSE) = 0.159812
	Correlation between actual and predicted = 0.916921
	Maximum error = 1.002173
	RMSE (root mean squared error) = 0.3134509
	MSE (mean squared error) = 0.0982515
	MAE (mean absolute error) = 0.124665
	MAPE (*mean absolute percentage error*) = *2.5819601*

- prioritization of participants in the design phase;
- procurement management; and
- defining projects program and goals.

The aforementioned factors, according to project managers, have a strong influence on the sustainability assessment of the preliminary design for facilities. It could be noted that they are mostly from the group of social aspects of project management, leading us to an important finding that the implementation of sustainability assessment depends on human factors. Although economic and environmental issues have a certain influence on sustainability assessment, project managers assessed them as less influencing factors for sustainability assessment than social aspects.

For the predictive model, the *coefficient of determination* R^2 = 0.84 and *mean absolute percentage error* (MAPE), MAPE = 2.58 (the percentage error of the model is around 2.58 per cent).

The model presented in this paper can be used for sustainability improvement of the preliminary design of future facilities' projects, and as a support in the decision-making process. Although the model is in context of the facilities' design preparation in the Republic of Macedonia, regarding the generality of the model, after the training phase, when GRNN is trained and the model is established, GRNN can predict the target variable for the new values for the predictors, and these values can be taken from a questionnaire made in any other country. The approach can be used as an experience for further predictive models for analyzing and predicting factors that are the most influential for assessment of the design sustainability at early design stage.

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Appendix

- How many employees does your company have: a. 1-9; b. 10-49; c. 50-249; d. more than 250.
- What is your work experience: a) less than 2 years, b) from 2 to 5 years, c) from 6 to 10 years, d) from 11 to 20 years e) more than 20 years?
- Circle the method/standard/methodology you have knowledge about: a. PMBOK b. PRINCE2 c. ISO 21500 d. PRISM e. none f. (other).

- Appointing project manager for a facility design.
- Defining projects' program and establishing projects' sustainable goals.
- Assessment of necessary resources required for the work on the project (human resources, equipment, materials, software etc.).
- Identification, assessment and treatment of projects' risks.
- Selection of method for sustainability assessment of facilities design.
- Work on several outline design proposals.
- Sustainability assessment of outline design proposals.
- Work on several preliminary design alternatives.
- Control and evidence of changes during design work, managed by responsible project member.
- Stakeholder prioritization during design phase regarding their power and influence over the design proposals.
- Resolving issues among stakeholders during project work.
- Inclusion of all key stakeholders in preliminary design preparing (investor, architect, civil engineer, electrical engineer etc., construction consultant, sustainable design consultant etc.).
- Participation of known and available future facility users.
- Motivation of the projects stakeholders.
- Equipment of the stakeholders with necessary resources during project work.
- Control of time schedule for realization of project activities.
- Monitoring contextual-external factors of the project during project work, such as: economy factors, legal, socio-cultural, science-technical-technological factors etc. and adjustment of the Preliminary design according to them.
- Monitoring and implementation of location factors during preliminary design work, such as: geographical, climatological, geological, hydrological, seismological, ecological etc. and adjustment of the preliminary design according to them.
- Selection of materials suppliers required during project work which implement sustainable business.
- Procurement management.
- Schedule and means of communication among projects' stakeholders.
- Software application during preliminary design preparing.
- Activities for preserving the knowledge and experiences acquired during the work on the design proposals.
- Closing of preliminary design phase.

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