Table 4 The relative error (%) between FEPRM prediction and actual energy simulation of five cases for extended testing

PROJECT	CASE	PREDICTED EUI	SIMULATED EUI	DIFFERENCE	RELATIVE ERROR*
Miami, FL	Case (a)	62.2	64.8	-2.60	-4%
	Case (b)	64.4	69.2	-4.85	-7%
	Case (c)	65.3	65.7	-0.46	-1%
	Case (d)	65.9	65.5	0.37	1 %
	Case (e)	63.6	66.2	-2.61	-4%
Chicago, IL	Case (a)	82.7	83.4	-0.71	-1%
	Case (b)	86.9	87.1	-0.19	0%
	Case (c)	83.0	86.6	-3.55	-4%
	Case (d)	93.0	85.5	7.51	9%
	Case (e)	79.9	77.7	2.16	3%
San Francisco, CA	Case (a)	51.1	53.1	1.99	4%
	Case (b)	51.8	53.6	1.77	3%
	Case (c)	58.6	56.0	2.63	5%
	Case (d)	54.72	51.0	3.68	7%
	Case (e)	49.1	49.7	0.59	1%

* Relative Error (%) = (Predicted EUI-Simulated EUI) / Simulated EUI

CONCLUSION

The FEPRM application is proposed as a form-based regression model for predicting energy performance of building models using a BIM tool. In order to study the usefulness FEPRM, three projects are studied on three different ASHRAE climate zones: Miami, FL (Zone 1A); Chicago, IL (5A); and San Francisco, CA (3C). Moreover, a series of extended tests are performed on 5 manually created forms for these 3 locations. The summarized features of FEPRM are provided in the following:

1. FEPRM is a significant improvement in the methodology of using regression-based models in predicting building energy consumption based on geometry variation. FEPRM uses project specifications defined by designer to create a data set of building geometries as the basis for regression models. Creating the regression model based on a data set that is specific to a project, increases the accuracy of prediction of the regression model. FEPRM relative error percentage was reported to be less than 5% for all of the case studies other than building models with courtyard. Higher relative errors of the regression models are reported in all of the studies available in the literature.
2. FEPRM provides instant energy usage feedback of the building model in a BIM interface. This enables the designer to modify the building geometry in the conceptual design phase and get instant feedback on the modification impact on energy performance of the model.
3. Being specific to a project, FEPRM enables the designer to be focused on the building form analysis by fixing the other parameters that could impact the energy performance such as building construction properties. It should be noted that FEPRM on the top of BIM provides the option for the user to set these parameters for the project before generating the building forms.
4. FEPRM uses more geometry related parameters to provide a more accurate representation of the building geometry. For instance, FEPRM uses the level height of walls and windows and their direction as building parameters in regression modeling.
5. The current version of FEPRM only generates convex shape floor plans. In future studies, authors will develop an algorithm using existing methods such as Cellular Automata, Shape Grammer, etc. to generate non-convex floor plans. It is predicted that generating non-convex floor plans will improve the FEPRM relative error for models with courtyard and more complex geometries.
6. Since FEPRM uses project specifications for creating regression models, it does not need any large database for training the regression models for accurate results. As discussed in this paper, a data set of 500 models could result to very accurate regression models.

In future studies, we will add non-convex floor plan generation to FEPRM. In addition, the form generation code will be optimized to reduce the wait time for the designer (the current FEPRM takes less than 1 hour to create 500 building forms). Furthermore, some visualization dashboards will be added to FEPRM to improve user interaction with the tool.

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