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SMALL SPACES NEED SMART SOLUTIONS: IMPACTS OF SMART INTERIOR DESIGN SOLUTIONS ON ACHIEVING FLEXIBLE SPACES

Salahaddin Yasin Baper [1*] **and Aisha Rashid Saied** [1]

[1] *Department of Architecture, College of Engineering, Salahaddin University-Erbil, Kurdistan, IRAQ.*

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ABSTRACT

Small spaces are results from lodging improvement and ongoing increasing residents; growing urbanization empowers individuals to less space. User's requirements are as yet the equivalent. The wellbeing risk of lodging improvement is discussing and highlighting by numerous articles; both claustrophobically and crowding sensing is demonstrated in flexible spaces. Physical flexibility relates to spaces that have the capability of being altered. A flexible space provides occupants some decisions over how interior space is organized according to his or her actions and preferences. This study explore effects of utilizing smart material on the process of construction and design and will analyze the structure of moving, fields of design, and interior architecture components for multi-functional usage with smart solutions to investigate the best approach to make interior architecture with flexible qualities, to reach the flexibleness state through prototyping for a studio apartment in the empire-Erbil city and detailed questionnaire, to improve recently recommended models. This research demonstrates the significant association between factors influencing the flexibleness small space from smart materials independent factors in terms of technological, formal, environmental effects, and holistic changes. In view of that prototyping, clarify flexible spaces and two route connections between smart analog model (SAM) and digital module (DM) cooperatively in the shape of models, these techniques are proper for smart spaces. SAM return smart spaces modeling by incorporating ICT implanted elements as actuators and sensors utilizing new innovations provide more possibility for interior elements not to be rigid. The outcome concluded that smart solutions would allow interior spaces to more flexibleness state.

Disciplinary: Architectural Sciences (Spatial Spaces Management).

1. INTRODUCTION

Today's society is influenced by urbanization and on-going developing populace, bringing about an expanding interest for bigger spaces (Lem, 2009). Using the idea of flexibility in interior architecture has profits in crises, altering the furnishing and structures for interior spaces that ought to be in a piece of execution and functionality (Emamgholi, 2011).

For thirty years ago a floor spaces that offering by small spaces around $55m^2$, the impression of what small spaces are completely altered (Jorgensen, 1990), occupants needs are as yet the same or possibly higher than previously to make human prosperity that is a lot of crucial needs that should be satisfied and kept up (Schmidt, 2009). The Royal Institution of British Engineer indicated the most widely recognized reason for user's dissatisfaction is the lack of space return to their spaces.

The existing interior architecture has utilized the most recent strategies and improvements in which arrived at the contemporary interior materials, and their procedures include smart materials, which provide substantial architectural conceivable outcomes for interior spaces (Rubnicu, 2012). The different researches managed with the meaning of these materials' potentials and utilization (Saidam, 2017). so the research issue in the lack of clearness of the effect of using smart interior design solution in modern interior design for achieving flexible spaces to find the impact of utilizing the characteristic of smart materials and advantages of systems of smart materials in interior architecture field, to investigate the best approach to make interior spaces with enhanced flexible qualities, to eventually reach the "flexibleness" state

This significant improvement has fortified progression in control solutions and Pc integrated systems for interior design systems that utilize smart interior design solutions in which can predict users' preferences, thus expanding comfortable lifestyle and flexibility, raising energy productivity that leads to accomplishing progressively flexible interior design (Wacks, 2002). Internet of things (LOT) and systems of building management make up the interior design essence and able to be utilized to energy control the systems of interior design, these systems give data about interior spaces and occupants preferences which able to be evaluated to accomplish better performance, and progressively efficient interior design arrangement(Smart buildings, 2013).

1.1 SMALL SPACES

A small space overwhelmed with light feels greater and brilliant and also gives a connection with outsides, which creates a lot of dissimilarity in terms of how you feel about the place. For a small space, smart solutions are an unquestionable requirement to display creativity. Max–Neef (1992) isolates the major human needs for nine critical factors which are protection, understanding, identity, leisure, subsistence, participation, affection, freedom, and creation, that each is significant for occupants prosperity, however, living in small spaces, the accompanying components ought to be generally fundamental including affection, subsistence, identity, and protection (Table 1).

Fundamental Human Needs	Being (qualities)	Having (things)	Doing (actions)	Interacting (settings)
Subsistence	Physical and mental health	Shelter	Feed, rest, work	Living environment, social settings
Protection	Care, adaptability	Security	Co-operate, plan, take care of, help	Social environment, dwelling
Affection	Respect, sense of humor, generosity, sensuality	Friendship, family	Share, take care of, make love, express emotions	Privacy, intimate spaces of togetherness
Identity	Sense of belonging	Home, work, customs, values	Make choices, grow	Places one belongs to, everyday settings

Table 1: Explanation of the essential factors for small spaces (after Max-Neef, 1992).

1.2 FLEXIBLE SPACES

The flexibility of spaces in interior architecture is to furnish interior spaces with simply altering that regard to changing in application and performance requirements. Even though interior spaces should be restricted and recognized through physical components as a wall, ceiling, floor, and etc., it ought to be designed such that changes flexibility.

1.3 PREVIOUS STUDIES ABOUT SMART INTERIOR DESIGN SOLUTIONS CONCEPT AND FLEXIBILITY IN INTERIOR ARCHITECTURE

The concepts of smart interior spaces have made a turning point over the recent three decades in interior architecture and construction fields. This turning position parallels development in computer technology, envelope designing, and building science, with the advanced techniques and innovations different smart buildings have been developing to grow high performing of interior buildings, because of these developments, smart interior design spaces are usually observed to be the future of the built environment. (Buckman et.al, 2014).

Albert (2002) suggested a model for smart technologies and trending interior design in the form of smart surfaces, materials, sensors, and systems of buildings to provide a gainful and practical built environment by enhancement of its four fundamental - management, structure, services, and systems (Figure 1).

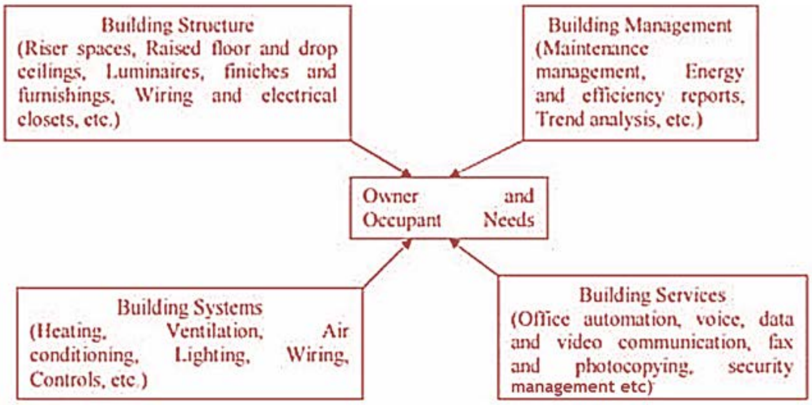

Figure 1: a combination of components of smart interior design to accomplish inhabitants and owner needs (after Albert, 2002)

Sekkei (2009) uses smart programming capable for estimating up building prerequisites for example (BIM) programming building information modeling, that BIM programming presented as a data archive for resources and sharing information for various design functions and qualities, Thus, BIM programming able to build up high practices with different advancement of interior design constructions and technologies. That supports designers to evaluate performance efficiency and also form a dependable reason for choice during lifestyle design.

Addington & Schodack (2005) demonstrate smart solutions for flexibility of interior design applying smart construction technologies to provide dynamism for design that required for contrasting functions: for example, phase changing pellets support to keep up and also control environmental impacts in interiors giving flexibility in smart materials and also in lighting to exchange the design atmosphere.

Ruuska & Hakkinen (2014) suggested a model for smart material's impact on the flexibility of interior design solutions. Materials that are smart have at least one characteristic that able to be substantially changed, for example, opacity, consistency, color, and form. There are different kinds of smart materials characteristics and concentrating on their actuation capabilities and ability to reacting to the flexibleness of spaces, which used in interior designs as dynamic and self-acting surfaces. Smart materials' main characteristics with property change capability, energy exchange capability, discrete size/location, reversibility properties.

Figure 2, Leupen (1997) demonstrate various degrees of flexibility in architecture design. This distribution depends on performative and innovative parameters in which show particular characteristics, so the performative and technical progressions increment in complexity terms from the left to right side.

Figure 2: Levels of flexibility in the order of sophistication (Leupen, 1997)

Liu et.al. (2010) defined. The third system of smart interior design is the system of (IoT) sensors for the structure of interiors to assemble information about light, space use, movement, and formation of a new area. Information analysis transforms the designs of the smart materials into expectant, responsive, and customized modifications to the environment of the buildings in real-time, subsequently fitting.

Mohammed (2015) links the use of smart materials and the possibility for introducing better interior design for more flexible to accommodate different users' needs that make them more convenient and comfortable. Smart materials, through their behavior and their properties, have a significant role in the flexibility of the space. The application of advanced technologies, using smart materials, has the capacity to improve the flexibility of interior spaces significantly. So, the development of smart materials reflected on the existing sensors and smart actuators for the interiors.

Saidam (2017) investigates the importance and the meaning of smart materials when utilized, which include the structural and physical, also an adjustment to extreme condition, and provide the research the most significant applications, and smart materials classification, in which upgraded the interior space's performance.

These previous studies deal with smart interior design solutions in small spaces for achieving space flexibleness, which shows the relationship between the smart material with interior architecture and physical elements of interior design. There can be three influences of smart material which are, formal, environmental, technological influences and holistic changes, these techniques work to make small spaces big and achieving flexible spaces by smart solutions for interior design as appeared in (Figure 3)

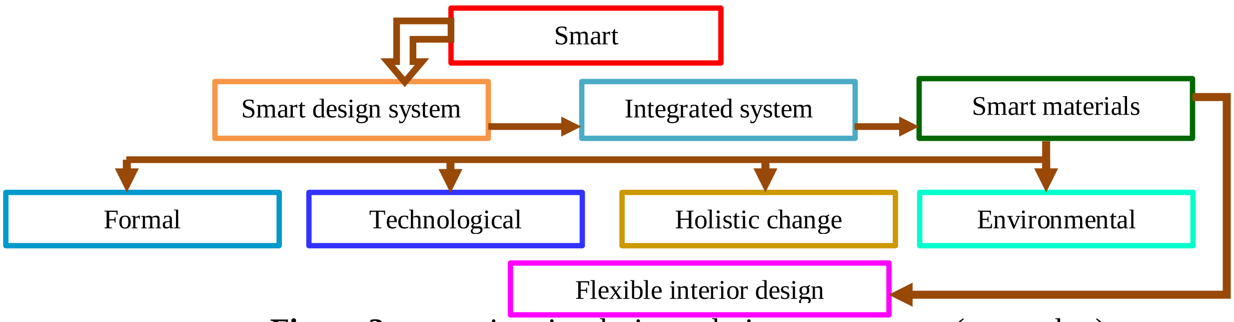

Figure 3: smart interior design solutions parameters (researcher)

2. METHODOLOGY

The methodology consists of three steps

Step 1) virtual tour by prototyping through smart interior design solutions

In this step, occupants obtain practical tours and look for a few prototypes about smart technologies.

Step 2) interior space arrangement

In this step are called the “daily living arrangement,” for seven prototypes, each of them with three different options, through smart interior design solutions.

Step 3) the final questionnaire

The second instrument for collecting data surveys designed regarding smart materials, formal, environmental, technological influences, and holistic changes, consists of 50 questions.

In this research, that include four independent factors that intended to cover the component of flexible spaces and one dependent variable (small space) to demonstrate the small spaces flexibleness, the hypothetical model (Tables 2 and 3) consist of one dependent and four independent variables organized to build up the survey.

Table 2: Sub factors summary of DV Variables.

NO.	Factors	Sub factors
1	Flexible Small spaces	Affection
		subsistence

Table 3: Sub factors summary of IV

1-Formal influences	structural level	Surfaces type	Double skin surfaces
			Interactive surface
		Modulation	conventional
			contemporary
		opportunity of alteration	Color
			transparency
			surfaces
			shape
		Relationship between spaces	related
			Separated
2-Environment influences	Self-adaptive	solar energy controlling	
		organize Ventilation system	
		light control	
	Resources fortification	energy consumption	
		Saving of materials	
	permanence	Resilience and rigidity	
		confrontation to natural features	
3-technological influences	Quality of Smart materials	Property change	
		Phase change	
		Energy change	
	Materials using	The interior surfaces as a whole	
		Parts of Wall, roof or ceiling	
	Materials function	structural	
		Aesthetic	
		environmental	
4-The holistic change	Slack change		
	Function change		
	Activity change		
	formation		

2.1 PRACTICAL TOUR THROUGH PROTOTYPES FOR SMALL SPACES

For prototypes applying, utilizing developed prototype application as a proposal for performing the task, so we take empire residential wings apartment studio about 67 m^2 in Erbil city as a case study for our prototyping design, the practical smart interior design solutions introduced in these prototypes compose of various smart techniques. Because of that a prototyping, through two route

*Corresponding author (S.Baper) Tel: +964-7504091111. Email: salahaddin.baper@su.edu.krd

integration between smart analog module (SAM) and digital module (DM) for flexibility of spaces is defined that SAM return to smart spaces models by ICT (information communication technology) that implanted for physical elements of interior design like actuators and sensors, utilizing these new technologies for interior spaces provide great possibility for elements to achieve more flexible state as in (Figures 4 and 5).

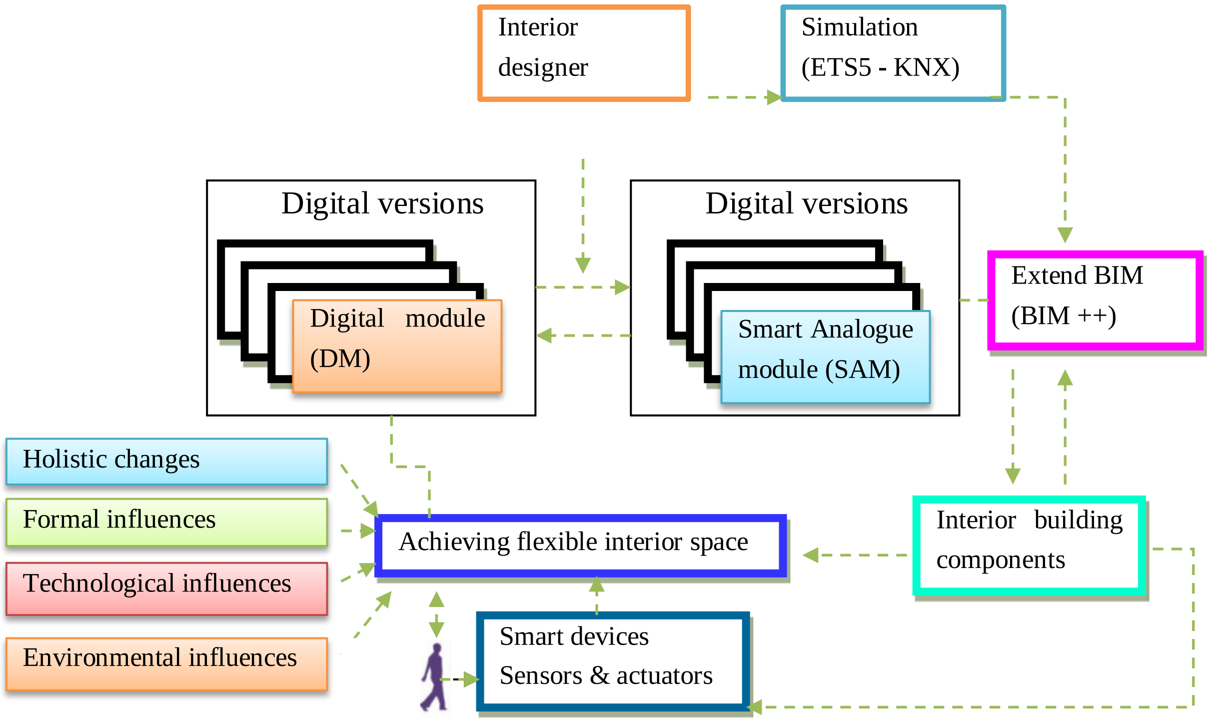

Figure 4: the objective of the prototype for achieving flexibleness in small spaces (researcher)

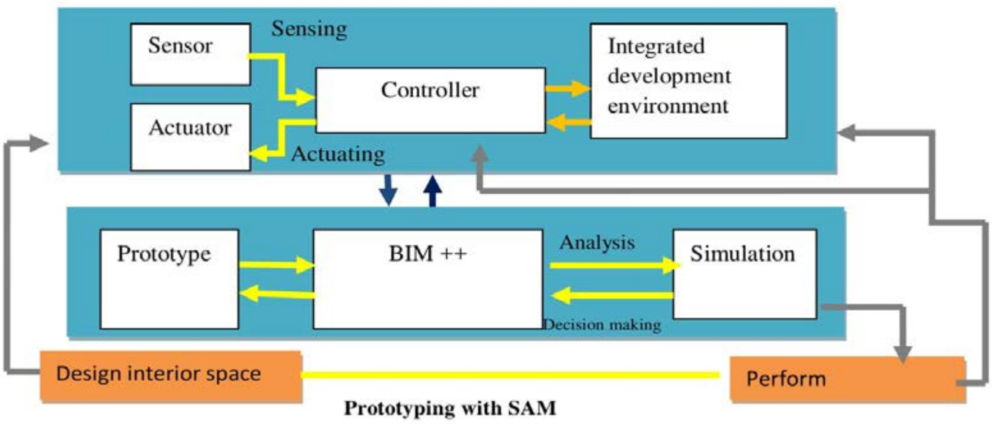

Figure 5: Prototyping design by ICT (Yi and Kim, 2012)

A model surveyed that either reacts to interior mood state or occupants task by SAM and DM collaboration.

1) Extended building information modeling(++ BIM) use occupants information joined with BIM
2) Simulation: integrated information of occupants is utilized for occupants task evaluating by simulation device
3) When the current model isn't completely satisfied with the occupant's performance, able to make a new prototype (Figures 6 and 7).

2.2 DAILY INTERIOR SPACE ARRANGEMENT FOR PROTOTYPES

Table 4 exhibits seven prototypes with different three options used in this study.

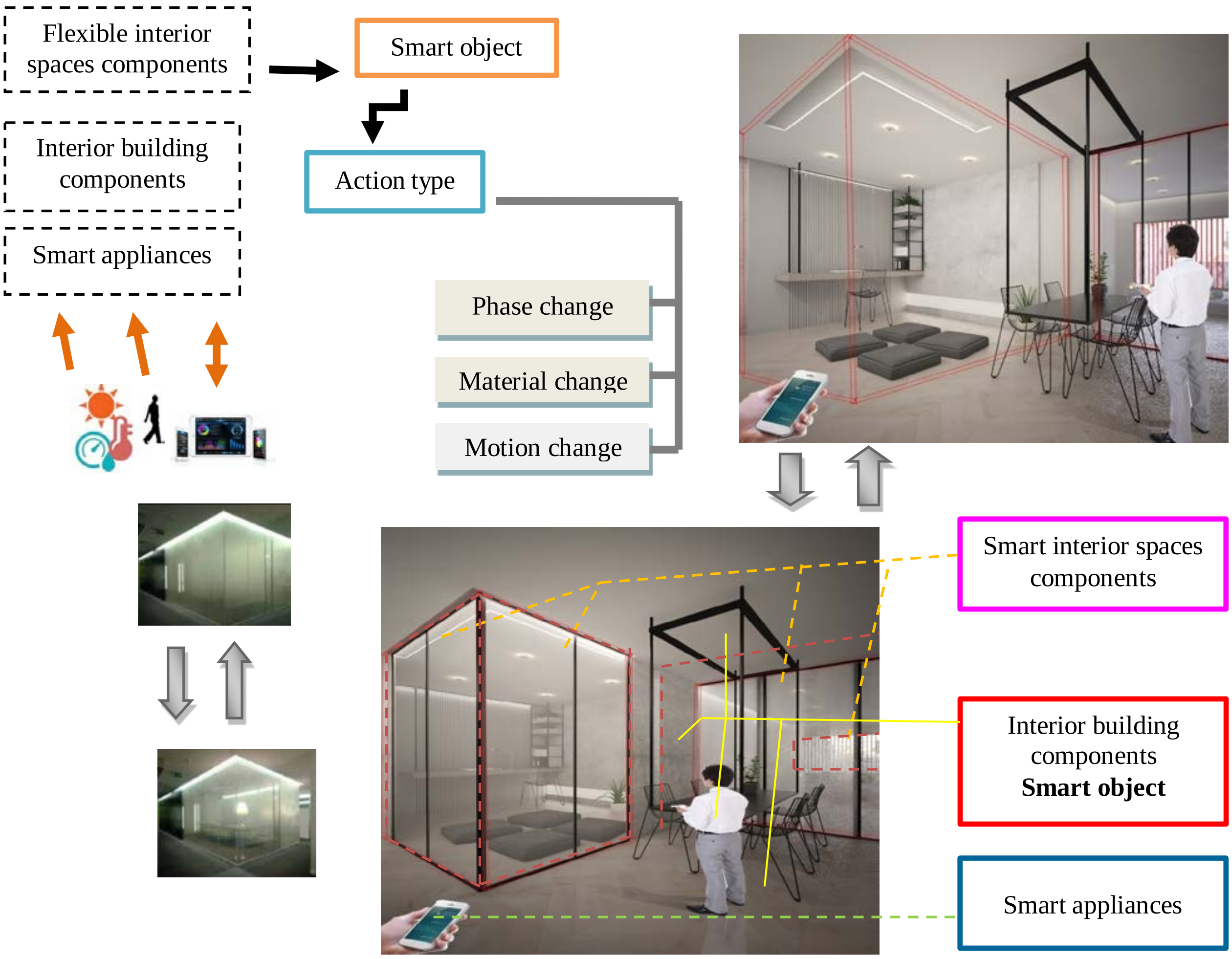

Figure 6: Extended BIM considering flexible space (researcher)

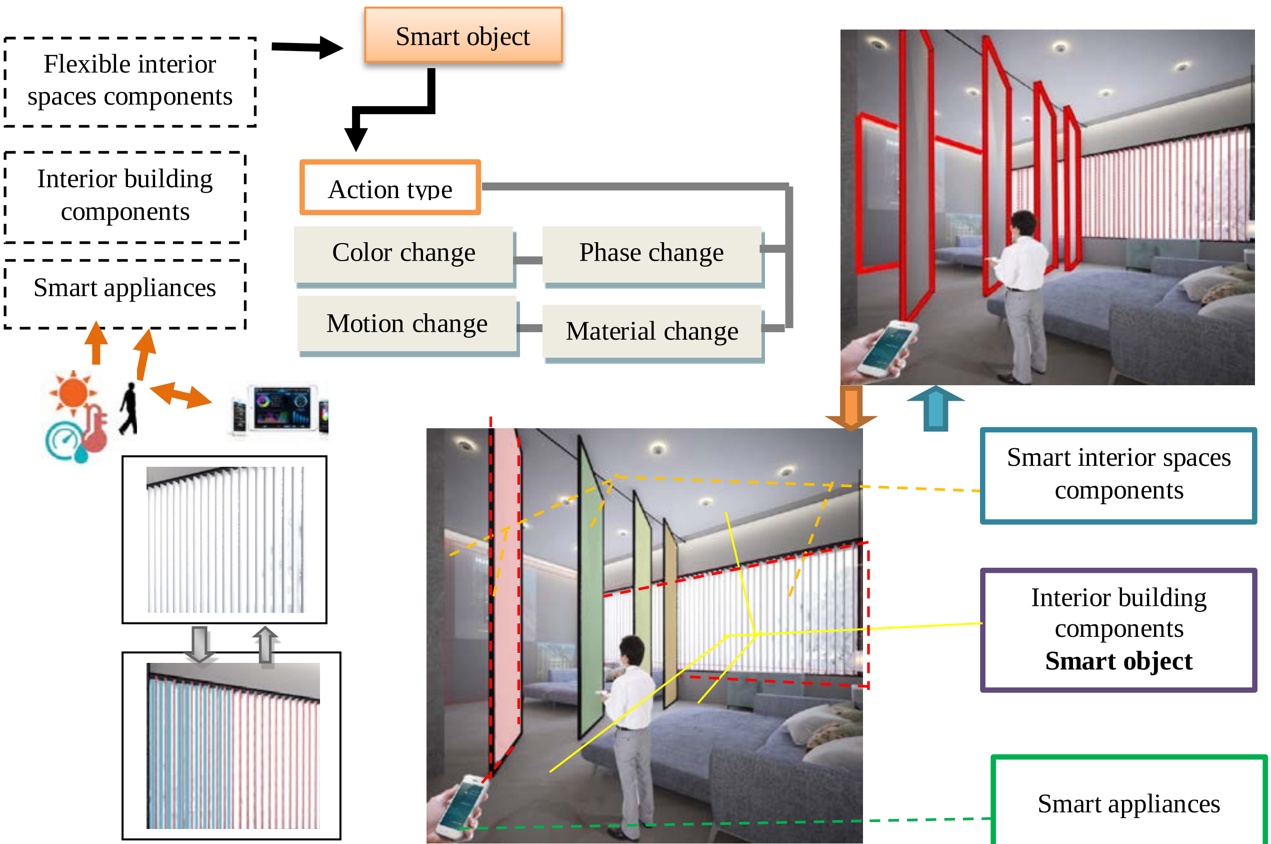

Figure 7: Extended BIM considering flexible space (authors' work).

*Corresponding author (S.Baper) Tel: +964-7504091111. Email: salahaddin.baper@su.edu.krd

Table 4: Daily interior space arrangements (authors' work).

Prototype NO.	Option 1	Option 2	Option 3
A			
B			
C			
D			
E			
F			
G			

In this section, the factors existing in the hypothetical framework and analyzing the statistics of selected models will be evaluated (see Table 5).

2.3 THE FINAL QUESTIONNAIRE

The research aim is to explore the significant relationship between variables influencing the small spaces, moreover, to test the relation of the variables to create an equation to show the best prevision for flexible spaces from smart solutions independent variables. The survey design is depending on the elements variable extracted from the literature review; in this way, the proportion of altering interior spaces would be concluded to achieve the flexibleness space through smart interior design solutions.

In surveys, the four principle qualities of smart materials for interior spaces were dividing into various sub-variables. The researcher gathered all data from the architects by hand, the furthermore statistical analysis estimated by utilizing IBM SPSS statistics 25.

Table 5: frequency rate for prototypes Table 4 (authors' work).

Item	Flexible spaces				A	B	C	D	E	F	G
X1	Formal influences	Structural level	Surfaces type	Double surfaces							
				Interactive surface							
			Modulation	conventional							
				contemporary							
			opportunity of alteration	Color							
				transparency							
				surfaces							
				shape							
			Relationship between spaces	related							
				separated							
X2	Environment influences	Self-adaptive	Solar energy controlling								
			Organize the Ventilation system								
			Light control								
		Resources fortification	Energy consumption								
			Saving of materials								
		Permanence	Resilience and rigidity								
			Confrontation to natural features								
X3	technological influences	Quality of Smart materials	Property change								
			Phase change								
			Energy change								
		Materials using	The interior surfaces as a whole								
			Parts of Wall, roof or ceiling								
		Materials function	Structural								
			Aesthetic								
			Environmental								
X4	holistic change	Slack change									
		Function change									
		Activity change									
		formation									

2.3.1 DATA COLLECTION

The advanced arrangement of this survey intended to decrease errors for measurement and improving the reaction ratio. The questioners dispersed arbitrarily to architects who work in various sectors, as consultant architect, private sector, governmental sector, and engineering teaching staff at Tishik international university and Salahuddin University, who they have an alternate scholarly capability, from 150 questioners, 121 returned, 20 disposed due to missing answers. Thus, 101-responded questionnaires are usable.

3. RESULT AND DISCUSSION

3.1 PROTOTYPING FREQUENCY RATIOS

As indicated by analyzing, the graphical investigation of criterion has been completed by dividing the number accomplished by one standing on the overall amount that multiplies by rate to get a percentage.

3.1.1 FORMAL INFLUENCE

The analyzing result at formal level to achieve flexible spaces through smart solutions of double skin interactive surfaces spread in a perfect world must have a different layer and optional covered profoundly layer of the exterior surfaces 39% utilizing this procedure, giving users the capability for decrease and increase the interior spaces easily, by having slack spaces as a long-term for systems of flexibility in which additional space left around the unit with the possibility to work in later, in which give the occupants make their small spaces bigger according to their preferences.

3.1.2 ENVIRONMENTAL INFLUENCE

Smart cover attempts to energy converse for interior spaces, 61.1% to lessen the use of energy for interior spaces, smart procedures that cooperate to make flexible spaces, energy proficient, and comfortable space for users. Smart glazing gives day-lighting and pleasant prospect to interior spaces, and also by completely opening mainly for small spaces, provides the chance to break down the exterior and interior barrier for small spaces to look bigger.

3.1.3 TECHNOLOGICAL INFLUENCES

Smart materials technologically can respond to the flexibleness of space by different properties %80 in which prompts change our senses to interior spaces either look enormous or small.

3.1.4 THE HOLISTIC CHANGE

The holistic influences accordingly leads to changing interior spaces functions %75 changes the role of smart object, interior spaces able to be arranged and used by creating proper connections as indicated by users activities, needs, smart analog model (SAM) by adjusting digital parameters of movements mechanically, when current model couldn't satisfy user's performance just by altering advanced versions to create new prototype according to user's preferences.

3.2 STATISTICAL ANALYSIS RESULTS

3.2.1 DESCRIPTIVE ANALYSIS

The descriptive analysis aim with the variables is to check the relationship between respondents' distinctiveness and their attitude toward the flexibleness for small spaces factors.

Consequently, by following statistical analysis was performed, in which the maximum mean among the smart materials Parameters was for technological influences with mean 3.45 and 1.13 for standard deviation (SD). Despite the fact that the minimum range of mean was for environmental impacts with 2.87 for mean and 1.10 for standard deviation. So the means of Formal, holistic change, small spaces were 2.97, 3.14, and 3.39, and for standard deviation 1.10, 1.12, 1.20 respectively, as appeared in (Table 6).

Table 6: Basic statistical analysis.

factors	Mean	SD	Rate of agreement (%)
Formal	2.97	1.10	59.43%
Environmental	2.87	1.07	57.39%
Technological	3.45	1.13	68.91%
Holistic changes	3.14	1.12	62.72%
Small space	3.39	1.20	67.83%

3.2.2 CORRELATION ANALYSIS

The correlation analysis aim is to evaluate the relationships of smart interior design solution factors (Formal, Environmental, Technological, and holistic change) and flexibleness for small spaces, accordingly, to describe the significant association between factors in achieving flexible spaces for small areas, also, to test the hypothesis.

In the context of that, correlation analysis (Pearson Product Moment Correlation Coefficient Test) used to investigate the relations between the factors, also to explain the strength and direction of the linear correlation between variables. Each independent variable is associated with a dependent variable. Correlation coefficients range from -1.00 to +1.00. The value of -1.00 represents a perfect negative correlation, whereas a value of +1.00 represents a perfect positive correlation. A value of 0.00 represents a lack of correlation (Kumarmake et al., 2005).

The correlation method was subjected to a two-tailed test of statistical significance from 0.05to 0.01. The data in (Table: 7) is illustrative of the outcome of Correlation Analysis to (Smart interior design solutions with achieving flexible spaces). The analysis reason is to verify the significant correlation between the independent factors (smart interior design solution) and the dependent factor (flexibleness of small space) by following the hypothesis were invented.

Table 7: Smart interior design solutions with achieving flexible spaces.

S	hypothesis	flexibleness for small spaces		Result
H1	there is a significant relation between smart material's formal impact parameter and flexibleness for small spaces.	*Corr.Coeff.* *(p-value)*	*0.317*** *0.001*	*significant*
H2	there is a significant relation between smart material's environmental impact parameter and flexibleness for small spaces.	*Corr.Coeff.* *(p-value)*	*0. 203** *0.043*	*significant*
H3	there is a significant relation between smart materials Technological impact parameter and flexibleness for small spaces	*Corr.Coeff.* *(p-value)*	*0. 321*** *0.001*	*significant*
H4	there is a significant relation between smart materials holistic changes parameters and flexibleness for small spaces	*Corr.Coeff.* *(p-value)*	*0. 144* *0.155*	*Non-significant*

**. significant Correlation at level 0.01 (2-tailed), *. Significant Correlation at the level 0.05 (2-tailed).

Table 7, the Smart materials formal impact parameter, Smart materials environmental impact parameter and smart materials Technological impact parameter have significant positive correlations with the (flexibleness for small spaces).

Likewise, the Except (Smart materials holistic changes parameters) variable is not significant correlated with flexibleness for small spaces. Consequently, the hypotheses $H_{1,}$ $H_{2,}$ and H_3 are accepted, but H_4 is rejected.

3.2.3 MULTIPLE REGRESSION ANALYSIS

The general purpose of multiple regressions in this study is to test the relationship between independent variables (smart interior design solutions) and a dependent variable (small spaces flexibleness).

In view of that, an equation stands for the best calculation of the flexibility of small spaces from independent variables of smart interior design solutions.

The recommended model was accessible by determining the cooperative impact of the independent factors, namely, (1) formal impact, (2) technological impact, (3) environmental impact, (4) and holistic changes impact concerning the general perceived of the small spaces flexibleness. In light of the previously mentioned, a regression model improved in resolving the relationships among factors. The subsequent model formed as:

$$\text{Flexible space} = \beta + \beta1\ \text{formal} + \beta2\ \text{environmental} + \beta3\ \text{technological} + \beta4\ \text{holistic} + \varepsilon \qquad (1)$$

Where, flexible space = the flexibleness for small space

β = constant of beta value
β1 = beta value of formal
β2 = beta value of environmental
β3 = beta value of technological
β4 = beta value of holistic, and
ε = error term

The summary of the multi regression model is appeared in (Table: 8), whereas the R^2 for the model is 0.386, suggesting that the smart interior design solutions variables explained 38.6% of the difference to the flexibleness of small spaces.

Table 8: Model Summary of multiple regression between independent and dependent factors

Model	R	R Square	Adjusted R Square	Error of the Estimate	Durbin-Watson
1	.386[a]	.149	.113	0.707	1.328

a. Predictors: (Constant), F, E, C, D

Generally, the smart material's formal impact parameter (β=0.390, p= 0.033) and the smart materials technological impact parameter (β =0.458, p=0.036) have significant positive relationships with the small spaces flexibleness. Results prove that "formal impact parameter" is most prominent in construing the flexibility of small spaces as each unit of the change in this parameter is interrelated with a 0.390 change in the small spaces flexibleness and each unit of "technological impact parameter" is interrelated with 0.458 changes in the small spaces flexibleness. Entertainingly, even non-significant, Environmental (β=0.041, p= 0.836), holistic changes (β= -0.076, p= 0.666) have positive associations with flexibility for small spaces (Table: 9)

Table 9: independent factors summarize by multiple regression analysis.

Parameter	B	Std. Error	Standardized Coefficients Beta	t	p
constant	.837	.718		1.167	.246
formal	.390	.180	.241	2.162	.033
environmental	.041	.196	.024	.207	.836
Technological	.458	.215	.234	2.133	.036
holistic	-.076	.175	-.049	-.432	.666
$R2=0.149$ Adjusted R Square=0.113 F=4.165 significance F=0.004 Significance at level 0.05 $p<0.05$ N=101					

Table 9 shows the multiple regression results analyzing. The beta values signify the unique contribution of all variable and which formulate in the model final equation as following.

Flexible =0.837 + 0.390 formal+ 0.041environmental + 0.458 technological + -0.076 holistic changes

4. CONCLUSION

Smart solutions are becoming more empowering to the interior design process, and we were able to implement them to create flexible spaces in a different way than was previously probable. As the flexibility of spaces for small spaces defined for multi-layers of functions throughout controlling functions and forms of interior building elements modified to user's needs, that prototyping was essential to realize smart solutions to allow interior spaces to more flexibleness state. This research determines the positive relationship between smart interior design solutions factors and the flexibleness of small spaces for studio apartments of residential wings in empire city /Erbil. The framework consists of Four factor (formal, Environmental, technological influences, and holistic changes) have begotten from recently proposed models. Throughout statistical results, the Pearson product-moment coefficient correlation revealed that (Smart materials formal impact parameter, Smart materials environmental impact parameter and smart materials Technological impact parameter) significant positive correlations with the (flexibleness for small spaces). Similarly, except for Smart materials holistic changes parameters, variables has very weak relationship with the dependent variable (flexibleness for small spaces).

Otherwise, multiple regressions results indicate that variables explained 38.6% of the difference to the flexibleness of small spaces, and illustrate that the smart materials formal and technological impact parameters have significant positive associations with the small spaces flexibleness. Results verify that "formal and technological impact parameter" is most influential in interpret the flexibility of small spaces as each unit of the change in these parameters is associated with the significant positive change in flexibleness for small spaces. While, even non significant, environmental, holistic changes have positive associations with flexibility for small spaces.

5. AVAILABILITY OF DATA AND MATERIAL

Information can be made available by contacting the corresponding author.

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Dr. Salahaddin Yasin Baper is a Lecturer in the Department of Architecture, the University of Salahaddin-Erbil, Kirkuk Road, Erbil City Kurdistan Region, IRAQ. He obtained his BS and M.Sc. in Architecture from the University of Technology, Baghdad Iraq. He earned his Ph.D. in Architecture from the School of Housing, Building, and Planning-USM Malaysia. His research encompasses Architecture, Design Studies, Architectural Technology, Architectural Identity.

Aisha Rashid Saied is a joint master student in the Department of Interior Architecture at Tishik International University and Salahaddin University-Hawler. She obtained her BS in Architecture from the University of Salahaddin, Erbil Iraq, in 2014. She is a Teaching Staff at the Architecture Department, Tishik International University. Her research interests include Spatial Small Spaces (SSS), Flexible Spaces.