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A MODEL PROPOSAL FOR SELECTING THE STRUCTURAL SYSTEM

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The choice of the structural system that crosses any space is the basic building design problem. Developments in building technology and materials science have provided innovative solutions to the problem of crossing space. In previous studies, criteria have been examined in the selection of structural systems, but it has not been clarified according to what / how to choose the product. To cross any specified space with the most suitable system and material is still a complicated process. In this study, it is aimed to choose the most suitable system by include decision makers into the model to minimize the possible losses. In the proposed method, selection criteria were created from the distinguishing features of the systems and intermittent scale method was used while determining the criteria values. A decision mechanism is created by evaluating these criteria values with the percentages set by the user. In this way, it has been observed that the selection process gives fast results as it is handled systematically, and it also provides flexible selection opportunities because it places the preferences in the foreground. The model can be used for develop material selection for structure, and this differentiation can be utilized as base study for future research. For complex product selection can be developed a software.

Keywords: Wide-span structure, Evaluation criteria, Selection methods, Structural design, Product evaluation, Construction industry.

1 INTRODUCTION

Structural systems that can exceed the opening determined in the design phase of any building have been highly diversified thanks to the developments in building technology and the innovations brought by materials science. This diversity brings up a choice and decision making problem. Determining the most suitable option is possible by evaluating all possible options according to the determined criteria. In previous studies, examples of criteria and decision models for system selection are presented. However, the system selection in these models is limited, made according to a certain opening or a pre-agreed material. Here the professional competencies or habits of decision makers step in. Putting out and choosing options for the specified clearance and specified material only limits the inclusiveness and effectiveness of existing decision models. The main problem focused on in this work is that this material and clearance is not a predetermined acceptance; it is to be considered as a criterion in decision making model. The fact that decision-makers' preferences are evaluated over the criteria in the model created and that their effect on the decision option can be observed makes this study different from other studies.

For this, firstly, the systems that passed the gaps were examined with the literature review, and the most prominent and distinct features of the systems were analyzed. Criteria have been established by determining their characteristics that will constitute an advantage or priority in choice. In this way, 33 options and 15 criteria were created. In the next step, the performances of each system in the criteria were evaluated. In the evaluation, lower and upper limit values were determined for each criterion in the light of regulations and practices. Tables were created by evaluating the performance of 1 to 5 systems according to each other with these values using the intermittent scale method. The values obtained from these tables define the benefit values of the options. When the utility values of the options are evaluated by the importance focus of the criteria determined by the decision makers, they give the emphasis of the option. The decision model is realized according to the decision maker's preferences in respect with the values of this evaluation.

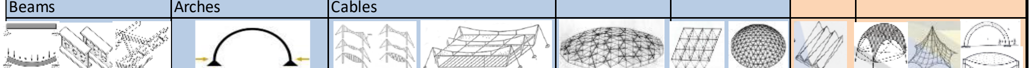
2 FINDINGS

2.1 System Selection Criteria

The selection of the system that can pass the specified opening is possible by determining the key criteria. In the study, the criteria that will enable the selection of load-bearing systems were determined in line with the distinctive features of the systems. These criteria are also the performance expected by the users and designers from the structural system of the building.

The criteria were examined in two groups in terms of their impact on usage performance and cost. Criteria related to usage performance were used in calculating the value in use, while the criteria that directly affect the cost of systems were used in calculating the exchange value. Since use value gives the benefit of the product and exchange value gives its cost, it is used "benefit" and "cost" as units of evaluation (Balanlı 1997). The criteria for value in use are examined as place of use, suitability for prefabrication, acoustic effect, suitability for installation, possibility of natural lighting, system cross-section according to the clearance (H/L), connection details, fire resistance. And the criteria for exchange value are examined also: system production energy, labor and machine requirement, manufacturing and assembly process, lifetime, detachable portability, recycling opportunity. While evaluating the performance of the options in these criteria, the systems have been numbered and classified in the Table 1 in order to make it easier to define the options and to follow them from the summary table. While classifying systems, material properties and form of creation, geometry were taken into consideration.

Table 1. System Classification.

SYSTEMS	BAR SYSTEMS														SURFACE SYSTEMS			
	One Direction Load Bearing System										Two Directions Loads Bearing System				Plane Surface Systems	Curvature Surface Systems		
	Straight Axis			Curved Axis							Cable Mesh		Space Truss					
	Beams			Arches			Cables											
																		
							Cable Beams		Cable Hangers									
STRUCTURAL MATERİAL	Solid Body	Void Body	Truss Body	Solid Body	Void Body	Truss Body	Single Layer	Double Layer	Cable Stayed	Cable Suspended	Single Layer	Double Layer	Plane Space Truss	Curved Space Truss	Plates	Shells	Tents	Pneumatic Systems
WOOD	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**							**S7**	**S8**				
STEEL	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**	**S16**	**S17**	**S18**	**S19**	**S20**	**S21**	**S22**				
CONCRETE	**S23**			**S24**											**S25**	**S26**		
PREFABRICATED CONCRETE	**S27**	**S28**		**S29**	**S30**										**S31**			
MEMBRANE																	**S32**	**S33**

2.1.1 Criteria for value in use

The criteria included in this title have been grouped and examined as use value, as they reveal the benefits of using the system that carries the cover. From these criteria; place of use, suitability for prefabrication, acoustic effect, suitability for installation, possibility of natural illumination, volume relationship (opening / system section), connection details while criteria regarding the production process of the system; fire resistance and resistance to environmental effects are the criteria regarding the usage process of the system.

Table 2. Options Benefit Values (Yd) on Interval Scale.

		VALUE MEASURE				
		← Lower Limit		----------------		**Upper Limit →**
		1	**2**	**3**	**4**	**5**
USAGE VALUE CRİTERİA	**Suitability for Prefabrication**	S23-S24-S25-S26	S1-S2-S4-S5	S3-S6-S7-S8	S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20-S21-S22	S27-S28-S29-S30-S31-S32-S33
	Acoustic Impact (Noise Control)	S33-S32	S12-S13-S14-S15-S16 -S18-S22-S26	S8-S17-S19-S20-S21-S24-S29-S30-	S4-S5-S6-S9-S10-S11-S25- S31	S1-S2-S3-S7-S23- S27-S28
	Availability for Plumbing	S33-S32	S1-S4-S9-S12-S23-S24-S29-S27-S31-S25-S26-	S15-S16-S17-S18-S19-S20-	S7-S8-S21-S22	S2-S3-S5-S6-S10-S11-S13-S14-S28-S30
	Natural Lighting Opportunity	S31- S25	S33-S32	S15-S16-S17-S18-S19-S20, S26	S1-S2-S3-S4-S5-S6-S9-S10-S11-S12-S13-S14-S23-S24-S27-S28-S29-S30	S7-S8-S22-S21
	System Cross Sectio	S15-S16-S17-S18-S19-S20- S31	S1-S2-S3-S4-S5-S9-S10-S11-S12-S13-S23-S24	S27-S28-S29-S30	S6-S7-S8-S14-S21-S22	S32-S33-S25-S26
	Connection Details	S22-S21-S20-S19-S18-S17-S16-S15	S9-S10-S11-S12-S13-S14-S25-S26	S1-S2-S3-S4-S5-S6-S7-S8	S27-S28-S29-S30-S31	S23-S24-S32-S33
	Fire Resistance	S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20-S21-S22	S32-S33	S23-S24-S25-S26	S27-S28-S29-S30-S31	S1-S2-S3-S4-S5-S6-S7-S8
	Recycling Capability	S33-S32	S1-S2-S3-S4-S5-S6-S7-S8	S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20-S21-S22	S25-S26-S23-S24	S27-S28-S29-S30-S31

2.1.2 Criteria for exchange value

Performance values, which give the exchange value of the options, are examined under 6 headings: system production energy, workmanship and construction equipment requirement, manufacturing and assembly process, service life, disassembly and recycling (Dağılgan 2019).

Since the criteria given here give values related to the cost of the system that passes the span, it is calculated as the exchange value and the option with the lower value is selected in contrast to the usage value.

Table 3. Evaluation of options according to their use and exchange value.

Options Benefit Value (Yd)		VALUE MEASURE ← Upper Limit ---------------- Lower Limit →				
		1	**2**	**3**	**4**	**5**
EXCHAGE VALUE CRİTERİA	**System Production Energy**	S23-S24 –S25-S26	S1-S2-S3-S4-S5-S6-S7-S8	S27-S28-S29-S30-S31	S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20-S21-S22	S32-S33
	Labor and Work Machine Requirement	S1-S2-S4-S5-S9-S10-S12-S13- S23- S24-S25	S3-S6-S11-S14	S7-S8-S27-S28-S29-S30-S31	S15-S16-S17-S18-S19-S20-S21-S22	S26-S32- S33
	Manufacturing and Assembly Process	S33-S32	S27-S28-S29-S30-S31	S1-S2-S3-S4-S5-S6-S9-S10-S11-S12-S13-S14	S22-S21-S20-S19-S18-S17-S16-S15-S8-S7	S26-S25-S24-S23
	Lifetime (Year)	S31-S30-S29-S28-S27-S26-S25-S24-S23	S9-S10-S11-S12-S13-S14-S21-S22	S1-S2-S3-S4-S5-S6-S7-S8	S15-S16-S17-S18-S19-S20	S32-S33
	Suitability for Prefabrication	S32-S33	S7-S8-S15-S16-S17-S18-S19-S20-S21-S22	S1-S2-S3-S4-S5-S6-S9-S10-S11-S12-S13-S14	S23-S24-S27-S28-S29-S30	S25-S26-S31
	Recycling Opportunity	S15-S16-S17-S18-S19-S20	S9-S10-S11-S12-S13-S14- S21-S22	S1-S2-S3-S4-S5-S6-S7-S8	S32-S33	S23-S24-S25-S26-S27-S28-S29-S30-S31

2.2 System Selection Model

The selection process starts with the determination of the place of use of the structure system and takes place by calculating the usage values for each option through summary tables. The benefit values were determined according to the lower and upper limit values of these criteria. In the selection stage, some of the options are eliminated depending on whether the model is intermediate or top cover in the first step. For the remaining options, the option benefit value will be determined in the summary table (Table 2-3). In the next step, these are scaled with the importance of the criterion determined by the designer and create the importance value of the option. In this way, the total usage values of all options obtained according to the importance for the same criteria are presented together (Eq. (1)).

$$\mathbf{G}\ (\text{Option Value}) = \mathbf{A}\ (\text{Criterion Importance}) \times \mathbf{Yd}\ (\text{Benefit Value of the Option}) \qquad (1)$$

In the model created, the criteria are grouped under two main headings as usage value and criteria giving exchange value. The usage and change values of the option are the sum of the option weights specified for each criterion. Comparison of the use and change values of the options constitutes the last step of the model. Among the values calculated for all options, the utilization value is the highest since it includes the performance criteria; on the other hand, since the exchange value includes the criteria for cost, the lowest one will be chosen.

2.3 Sample Application

In this section, described model will be exemplified for the mezzanine floor of the two-story workshop and the span is 35m x100m. It is assumed that the importance given by the user to the criteria is shown in Figure 4.

Table 4. Criteria importance value given by the user.

Usage Value Criteria	Importance (%)	Exchange Value Criteria	Importance (%)
Suitability for Prefabrication	25	System Production Energy	15
Acoustic Impact	10	Labor and Work Machine Requirement	20
Suitability for Plumbing	5	Manufacturing and Assembly Process	35
Natural Lighting Possibility	15	Lifetime	30
System Cross Section	10	Disassembled Portability	0
Connection Details	5	Recycling Opportunity	0
Fire Resistance	20		
Environmental Impact Resistance	10		
Total Usage Value	100	Total Usage Value	100

1[st] step: The structure for mezzanine floor is determined as; S1, S2, S3, S9, S10, S11, S23, S25, S27, S28, S31 as shown in Table 2.

2[nd] step: For S1, S2, S3, S9, S10, S11, S23, S25, S27, S28, S31, in the light of the system features described in the previous sections, will be calculated showing the benefit values of the options in the criteria for the options specified in Table 3 - 4. In this way, the utility values of each option for all criteria will be determined.

3[rd] step: The utility values determined for the options are multiplied by the importance given by the user with the help of the Table 4, and each option use value and exchange value are calculated. Choosing the option with the highest usage value and the lowest change value among the options is the last step of model.

Table 5. Criteria importance value given by the user.

		USAGE VALUE CRITERIA									EXCHANGE VALUE CRITERIA						
		Suitability for Prefabrication	Acoustic Impact	Suitability for Plumbing	Natural Lighting Opportunity	System Cross Section	Connection Details	Fire Resistance	Environmental Impact Resistance	**Total Option Value**	System Production Energy	Labor and Work Machine Requirement	Manufacturing and Assembly Process	Lifetime	Disassembled Portability	Recycling Opportunity	**Total Option Value**
Importance Weight (A)		**25**	**10**	**5**	**15**	**10**	**5**	**20**	**10**	**G**	**15**	**20**	**35**	**30**	**0**	**0**	**G**
WOOD	**S1**	2	5	2	4	2	3	5	2	325	2	1	3	3	3	3	245
	S2	2	5	5	4	2	3	5	2	340	2	1	3	3	3	3	245
	S3	3	5	5	4	2	3	5	2	365	2	2	3	3	3	3	265
	S9	4	4	2	4	2	2	1	3	290	4	1	3	2	3	2	245
	S10	4	4	5	4	2	2	1	3	305	4	1	3	2	3	2	245
	S11	4	4	5	4	2	2	1	3	305	4	2	3	2	3	2	265
CONCRETE	**S23**	1	5	2	4	2	5	3	4	290	1	1	5	1	4	5	240
	S25	1	4	2	1	5	2	3	4	250	1	1	5	1	5	5	240
PREFABRICATED CONCRETE	**S27**	5	5	2	4	3	4	4	5	425	3	3	2	1	4	5	**205**
	S28	5	5	5	4	3	4	4	5	**440**	3	3	2	1	4	5	**205**
	S31	5	4	2	1	1	4	4	5	350	3	3	2	1	5	5	**205**

The summary table obtained by comparing the use and change values of the options in these criteria according to each other is given in Table. 5.

When the tables are examined, it is seen that the option with the highest usage value is S28 - Prefabricated concrete hollow body beam. Although there are three options with the lowest change value, the common option is S28 - Prefabricated concrete Void body beam.

3 CONCLUSION AND RECOMMENDATIONS

While making functional, aesthetic and material-related decisions, the choice of the carrier system covering the building is an important variable that affects these decisions. The choice of this variable is in response to the criteria taken into account in building performance evaluations.

Developing technology and application forms in materials and production fields increase the number of options and make selection difficult. Choices made with the own experience and trend applications of the technical staff involved in building design and implementation do not always provide the most effective and efficient system. Since it is not a model for technical staff to evaluate and compare all options together, there may be losses based on more time and effort than necessary, and problems such as high costs may be encountered. In this study, a model is proposed that will enable systematic evaluation of all options together. By giving importance to the criteria, it was aimed to include the designer in the decision mechanism, and a choice was made specific to the structure.

The model created in the study was tested hypothetically with the sample application. In the sample application, it was observed that the importance given to the criteria by decision makers was effective in determining the option. Since the selection of the system covering the opening to be passed in every designed space should be specific to that project, the preferences of the decision makers gain importance. This gives the result that decision makers should be included in the decision mechanism and also the project-specific decisions are effective in system selection.

With the study, a product selection method has been introduced, and it is foreseen to create a base for future studies, and to be able to use other structural elements or components such as the carrier system for selection decisions.

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