Conceptual Design of Recyclable Waste Recovery Automation

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Introduction

Recycling has become a necessity as a result of rapidly depleting natural resources. Many civilizations in history have reused scrap metals by melting helmets, swords and various metal parts they used in furnaces and pouring them into molds, making metal money, etc. needed items. These studies have been the foundations of recycling.

As the most important goal of waste materials recovery targets, these materials can be used in addition to our natural resources used in the production sector. In recent years, when industrialization has increased, the need for natural resources has increased rapidly, and recycling processes have become a necessity with the rapid depletion of existing natural resources. On the other hand, instead of procuring and processİng these resources in raw form, wastes obtained with less cost provide large-scale benefits to economies. In the 1800s, a deposit system was introduced for the sale of bottles contaİnİng liquids and the sold bottles were started to be collected again. In 1813, Benjamin Law made pure cotton from idle textile products. During World War 2, the raw material problem increased significantly and the importance of recyclable materials was realized. Various announcements and campaigns were made in Europe to raise public awareness about recycling. In this way, they were asked to support their countries. Waste materials collected in recycling are classified as plastic, glass, paper, etc. by passing through a sortİng center. The machine we will design in this study will be a machine for the collection of waste materials by separating them at the source. The system will be designed by conceptual design method. Conceptual design steps will be discussed and the ideal design selection will be aimed by usİng the method.

In their work, which presents a systematic approach to engineering design, they explained systematic design in four main steps: clarification of purpose, conceptual design, shaping design and detailed design. They explained the steps of conceptual design and gave detailed information about its use (Beitz et al., 1996). He conducted his studies on web-based conceptual design and implemented the design system on the web. As a result of this work, the margİn of error was minimized and the design was easier to use. It has created a solution space that can be continuously improved and enabled comprehensive thinking in new designs (Mayda, 2007: 119). In his study, he used conceptual design to develop a stair lift for the elderly and disabled people and achieved successful results. In his study, he determİned the basic function by abstracting and divided it İnto sub-functions. He developed solution proposals for the sub-functions he created. As a result of the conceptual design process, he determined the most appropriate design among the solution alternatives and designed an innovative system (Bozbuğa, 2018: 120). In their study, they used conceptual design to design a new lawn mower. They concluded their work with a design with high innovative value (Börklü & Erdemir, 2019). In his study, he discussed the conceptual design approach together with other design approaches on different examples and showed practically that a good conceptual design solution can be obtaİned when these approaches are used together (Şanlier, 2019: 119).

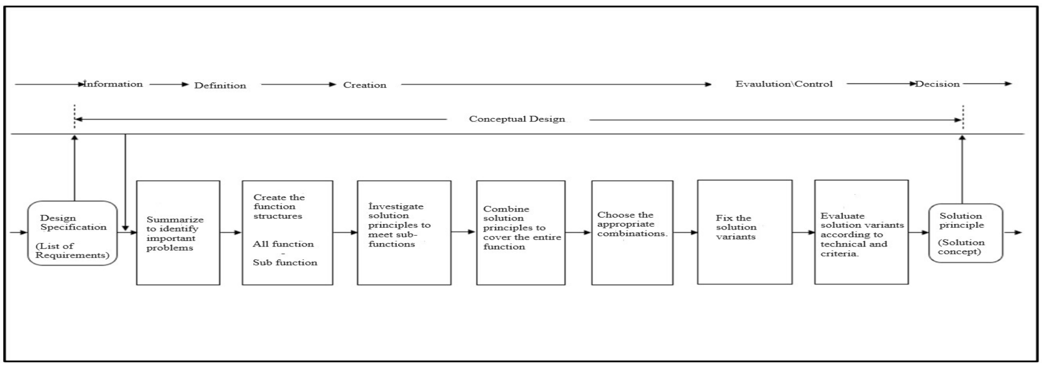
Material And Method

Conceptual design is an important part of the systematic design approach in which the basic solution path is presented through elaboration. The German scientists (Beitz et al., 1996) introduced the systematic engineering design, which consists of four main stages;

- Clarifying the purpose
- Conceptual design
- Forming design
- Detailed design

In the conceptual design phase, design alternatives are eliminated through systematic evaluations and the most ideal design is selected. Creative solutions are realized at this stage. Conceptual design consists of nine steps. The conceptual design stages given in Figure 1 start with the creation of the design specification. Problems are clearly defined and summarized. Then, function structures are created and sub-functions appropriate to these structures are determined. Solution methods that can respond to these sub-functions are investigated. The solution methods found are combİned to correspond to the whole function. Appropriate combinations are made. Solution variants are fixed. These variants are evaluated accordİng to technical and economic criteria and the solution concept is expressed.

Figure 1
Conceptual Design Steps



In this study, we will design a recycling vending machine for the collection of paper and plastic wastes at the source using the steps shown in Figure 1.

Design Specification Preparation

In this step, the design is considered from a broad perspective and a list of wants and desires for the system is created. Here, wants are denoted by "I" and are system features that must be met absolutely. Desires are denoted by "A" and are features that can be met withİn the possibilities. It is possible to update this list durİng the design process (Şekercioğlu,2019).

Table 1
Checklist for Design Specification Preparation

Maİn title	Examples
Geometry	Size, height, width, diameter, number
Kinematics	Direction of movement, speed, acceleration
Force	Force direction, magnitude, frequency, deformation
Energy	Pressure, temperature, heating, cooling, capacity
Material	Physical and chemical properties, auxiliary materials
Signal	İnput, output, control instruments and devices
Safety	Direct safety, environmental safety
Ergonomics	Height adjustment, lighting, shape
Manufacturİng	Maximum part size, suitable production method, tolerance
Quality control	Test and measurement facilities, conformity to standards
Assembly	Installİng, positionİng, foundation preparation
Transport	Area, mode of transport, environment and natural conditions
Operation	Sound level, wear, operatİng environment (acidic, basic)
Recyclİng	Reuse, storage
Cost	Acceptable manufacturİng cost, investment and depreciation
Business plan	End date, planning and control, delivery date
Maintenance	Service İntervals, inspection, replacement, repair

We can facilitate our assessment by using the checklist given in Table 1 to prepare the list of needs.

Figure 2
Waste Collection Vending Machine Design Specification

I/A	Needs
I	Paper And Plastic Shall Be Defined As Waste Material
A	Additional İtem Defİnitions Can Be Made As Functional Design.
I	The Maximum Weight Of Waste Materials Should Be As Follows, $G_{MAX\ WASTE} = 5$ kg
I	The Maximum Waste Size That Can Be Collected Should Be As Follows. $W_{MAX} = 25$ cm, $L_{MAX} = 35$ cm, $H_{MAX} = 10$ cm
I	Waste Inlet Openİng Should Be Maximally As Follows $W_{MAX} = 27$ cm, $H_{MAX} = 12$ cm
I	Vending Machine Dimensions Should Be Designed İn Such A Way That Each İndividual Can Use It Comfortably
I	Payment Will Be Made İn Return For Waste (Coins, Chips, Stamps, Etc.).
I	Safety And Security Measures Must Be Taken
I	System Sensitivity Must Be High
I	Should Be Manufactured From Easy-To-Produce Parts.

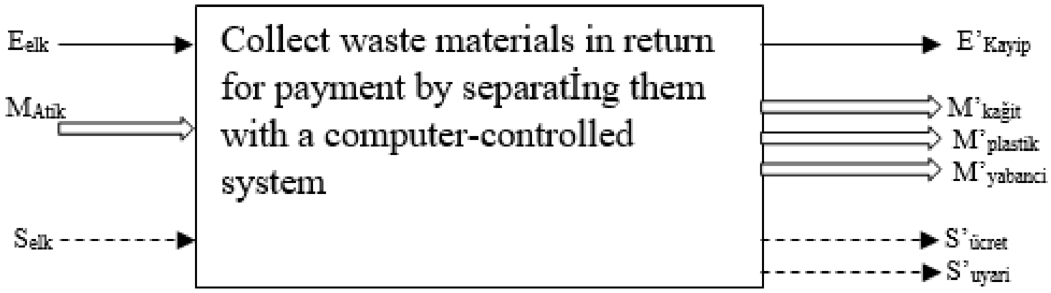
Figure 2 shows the specification for the design of the waste collection vending machine. Here the wishes and desires are clearly stated and the design is guided accordİngly.

Creating Function Structures

Function structures are handled in two groups. First, the whole function is determined. Then it is decomposed into sub-functions to be detailed.

Figure 3

Full Function of Waste Vending Machine Design



First of all, the entire function diagram of the designed system is revealed to express its main purpose. In the system, inputs and outputs are expressed as energy "E", material "M" and signal "S". Inputs to the system are expressed as "E-M-S" and outputs as "E'-M'-S'". Figure 3 shows the energy, material and signal inputs and outputs of the waste vending machine design. The most general expression of the system is "sort waste materials with a computer-controlled system and collect them in return for payment".

Sub-functionalisation

By dividing the whole function structure, sub-function structures are created as in figure 4. The whole function structure is more complex than the sub-function structure. Dividing in this way finds the most suitable startİng point for solving the problem. A better understanding of the system is achieved. The design can be modified by addİng or removing function structures.

Figure 4

Dividing the Entire Function Scheme Into Sub-Functions (Beitz et al., 1996)

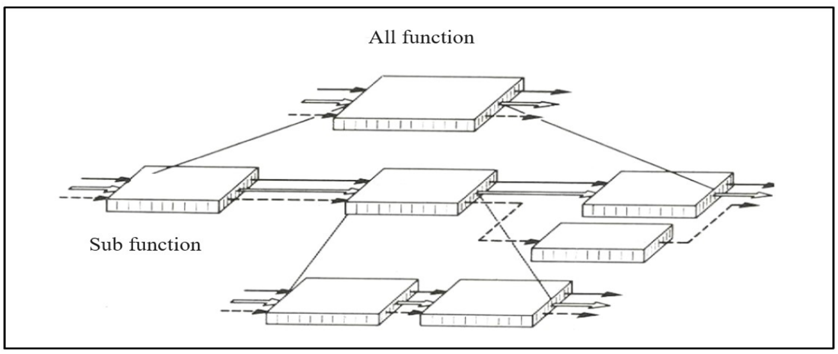
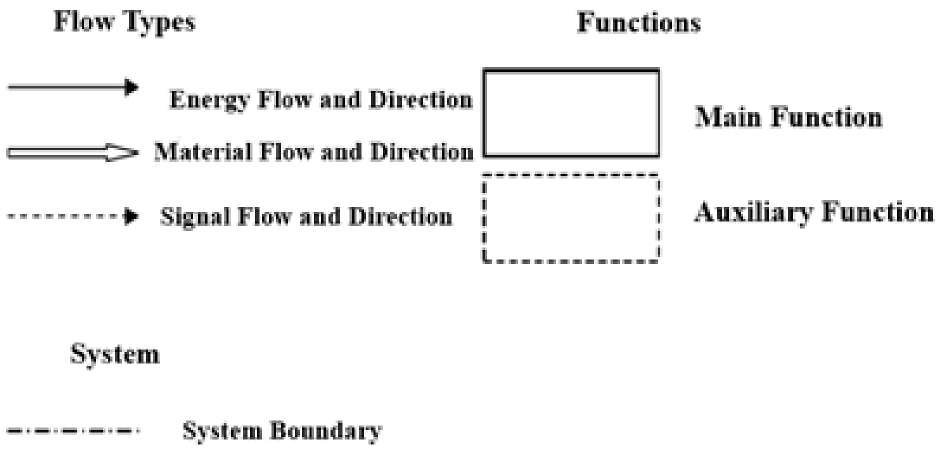


Figure 5 shows the symbols used to represent functions. Considerations in developing function structures;

- It should be in an evolving order.

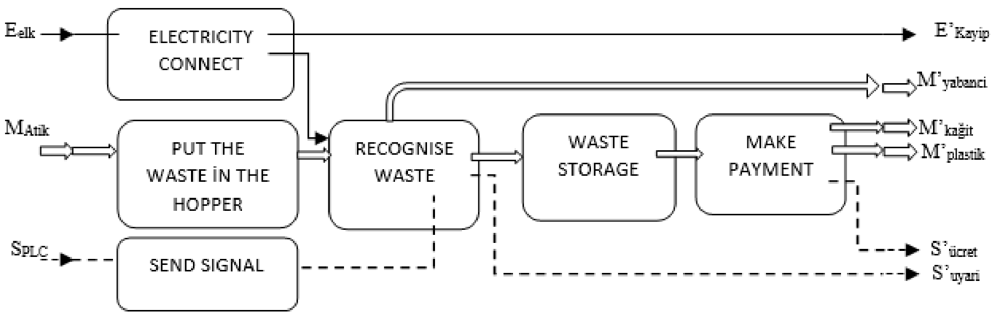
- It should be simple and straightforward.
- They should be represented by standard symbols.
- Different solution concepts should be generated.
- Generally valid function blocks should be used.
- Energy, material and signal data must be defined.

Figure 5
Symbols Representing Functions (Mayda, 2007: 119)



The diagram of the sub-functions of the waste vendİng machine design is shown in Figure 6. In this figure, the workİng system is divided into sub-functions.

Figure 6
Waste Vending Machine Sub Function Diagram



Establishing Solution Principles

Solution options are created for the design with all functions and sub-functions defined. These solution options are shown in a table called morphological card (Table 2). A sufficient number of solution options are created by combining the solution variants in the morphological table.

Table 2
Morphological Card for Waste Vending Machine

Solution Path / Sub Function	C1	C2	C3	C4
Power	Electric Energy	Solar Energy	Electricity And Solar Energy	Battery
Control	Manual Control	Remote Control	Computer	
Product Identification	Object Recognition	Camera		
Waste Diversion	Pneumatic	Electric	Hydraulic	
Warning/Effect	Lighted	Sound	Illuminated And Audible	
Material	Stainless Stainless Sheet	Plastic	St 37 Sheet	

Combining Solution Principles

Table 3
Waste Vending Machİne Conceptual Design Options

SOLUTION PATH / SUB FUNCTION		C1	C2	C3	C4
1	POWER	ELECTRIC ENERGY	SOLAR ENERGY	ELECTRICITY AND SOLAR ENERGY	BATTERY
2	CONTROL	MANUAL CONTROL	REMOTE CONTROL	COMPUTER	
3	PRODUCT IDENTİFİCATİON	OBJECT RECOGNITION	CAMERA		
4	WASTE DIVERSİON	PNEUMATİC	ELECTRIC	HYDRAULIC	
5	WARNING/EFFECT	LIGHTED	SOUND	ILLUMINATED AND AUDİBLE	
6	MATERIAL	STAINLESS STAINLESS SHEET	PLASTIC	ST 37 SHEET	

Solution alternatives for waste vending machİne design are created by making selections from the morphological card created in Table 3.

Tablo 4
Design Alternatives Table

Black CV-1	1-C1,2-C3,3-C1,4-C1,5-C1,6-C3	Green CV-4	1-C2,2-C1,3-C1,4-C1,5-C2,6-C1
Yellow CV-2	1-C1,2-C3,3-C1,4-C2,5-C2,6-C3	Gray CV-5	1-C3,2-C3,3-C1,4-C2,5-C2,6-C3
Orange CV-3	1-C1,2-C2,3-C2,4-C3,5-C2,6-C3	Blue CV-6	1-C4,2-C3,3-C2,4-C3,5-C3,6-C2

Selection of Suitable Joints

When the part of creating design alternatives is completed, the designs that may be suitable among these alternatives are selected. For this process, a selection card table is created as shown in Figure 7. In this table, the elimİnation process is carried out accordİng to the followİng selection criteria and efforts are continued to collect missing information. These selection criteria are;

- Compatible with all functions
- Meeting the list of needs
- Being doable
- Being within cost limits
- Ensuring safety measures
- Preferred by the designer

Figure 7

Waste Vending Machine Conceptual Design Selection Card

Election Card									
Solution Variants	Election Criteria (+) Yes (-) No (?)Lackof Information (!)Check Condition							Decision Decision Criteria (+) Sustain Solution (-) Take Out The Solution (?) Collect İnformation (!)Check The List Of Requirements For Changes	
	A Compatible With All Functions	B Meets Specification Requirements	C İn Prİnciple İt Can Happen	D Allowable Cost	E Meets Safety Requirements Directly	F Beİng A Designer Preference	G Sufficient İnformation	Opİnions (Reasons)	
Cv-1	+	+	+	-	+	-	+		+
Cv-2	+	+	+	+	+	+	+		+
Cv-3	-	+	+	-	-	+	?	Not Enough İnformation	-
Cv-4	-	+	+	-	-	-	+	High Cost	-
Cv-5	+	+	+	+	+	-	+		+
Cv-6	+	+	+	-	+	-	?	Not Enough İnformation	-

Fixing Solution Variants

In this step, we will focus on the design alternatives that we have selected in the selection card as maintaining the solution. We will consider the rough scale drawings for these designs and evaluate the designs. Rough calculations can be made if necessary. Definitions can be expressed by creatİng kİnematic models. Technological market research is conducted. Solutions can be better evaluated in the light of this data. System properties of alternative concepts are expressed.

Figure 8
Waste Vending Machine Conceptual Design Solution Variant-1

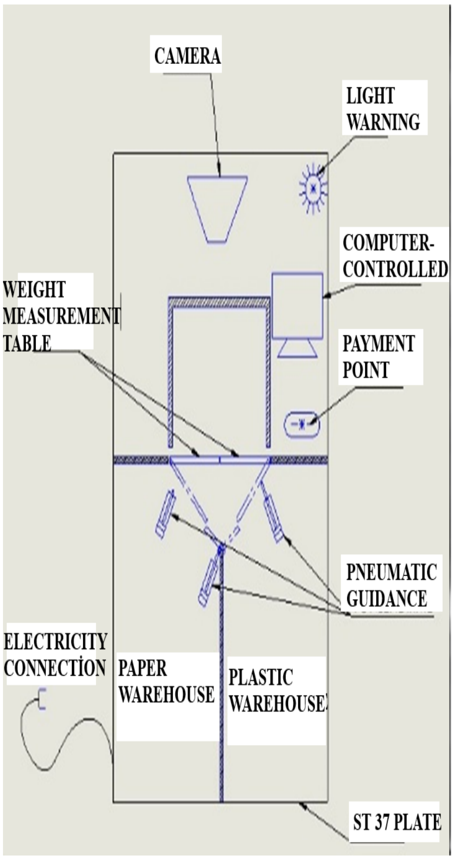
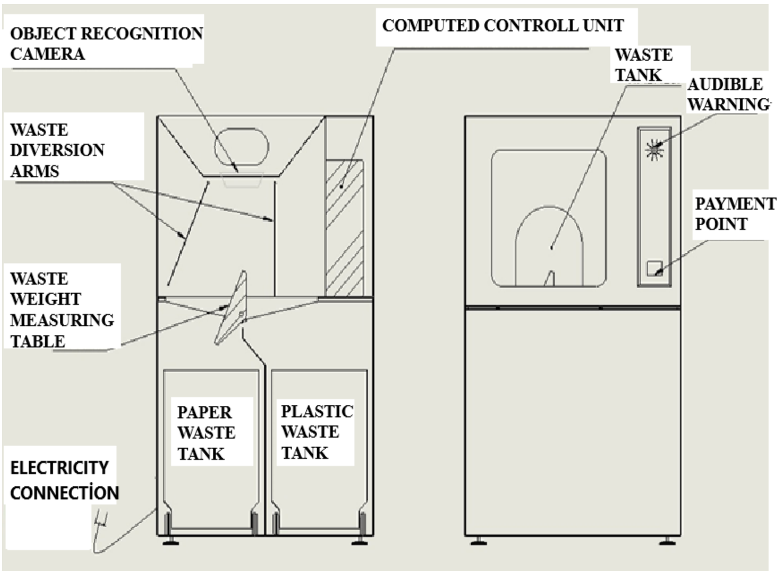


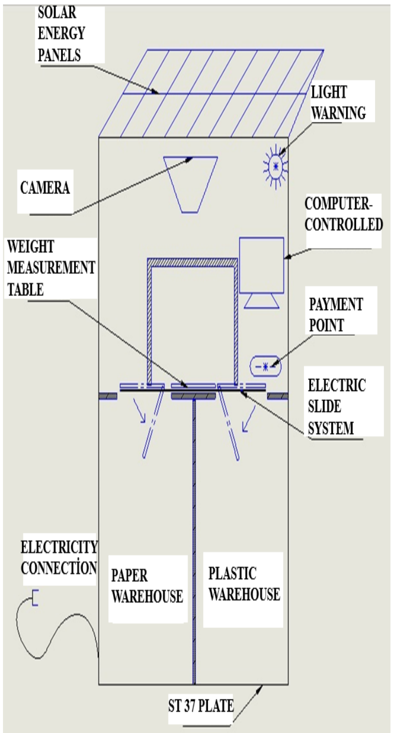
Figure 8 shows our design alternative which is electrically operated, computer controlled, includes object recognition technology, the steering mechanism works with pneumatics, has illumİnated warnİngs and can be produced from ST-37 sheet metal. Storage is fixed inside the machİne.

Figure 9
Waste Vending Machine Conceptual Design Solution Variant-2



In Figure 9, there is a design alternative that is electrically operated, computer controlled, has object recognition technology, the steering mechanism works with electric pistons, can make audible warning and can be manufactured from ST-37 sheet metal. There is an easily changeable storage system.

Figure 10
Waste Vending Machine Conceptual Design Solution Variant-5



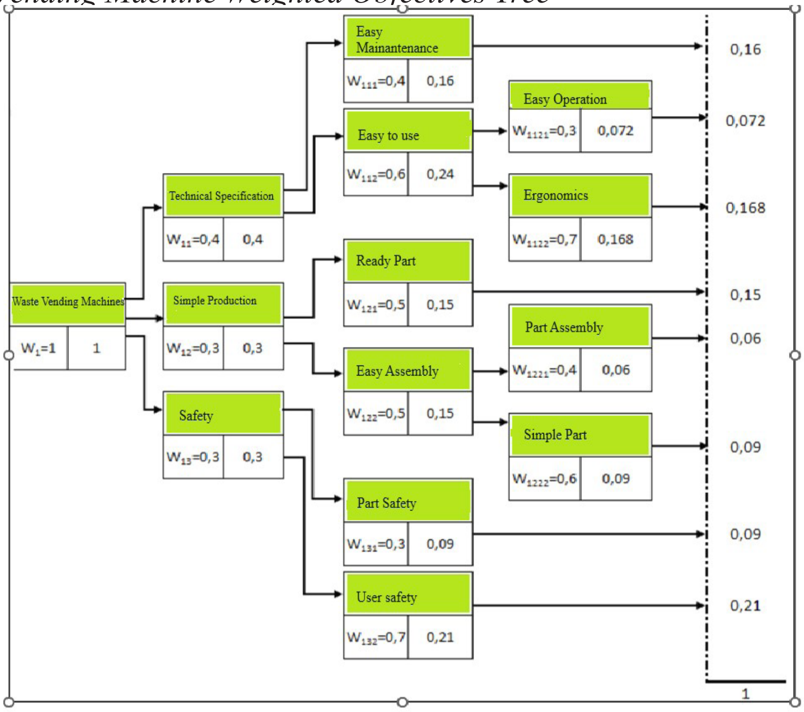
The design alternative shown in Figure 10 is a conceptual design of a vending machine powered by electricity and solar energy, computer controlled, with object recognition technology, waste routing with electric slides, with an audible warning system and designed from ST-37 sheet metal.

Evaluating Solution Variants According to Technical and Economic Criteria

Among the conceptual design alternatives evaluated in the selection card, the designs that are positive are re-evaluated and the most appropriate solution method is selected. At this stage, firstly, the objectives tree is created. Here, evaluation is made accordİng to the criteria. Percentage values are assigned accordİng to their importance. In the last part, the sum of values should be ‘1’.

Figure 11

Waste Vending Machine Weighted Objectives Tree



An evaluation chart is prepared according to the criteria and values determined in Figure 11.

Table 5

Waste Vending Machine Evaluation Table

Evaluation table				Solution-1			Solution -2			Solution -5		
Criteria		W	Parameters	Ratio	Value	Weight Value	Ratio	Value	Weight Value	Ratio	Value	Weight Value
1	Easy maintenance	0.16	Easy maintenance	Middle	8	1,28	More	9	1,44	Middle	7	1,12
2	Easy operation	0.072	Easy to use	Middle	6	0,432	More	8	0,576	Middle	5	0,36
3	Ergonomic	0.168	Ergonomics	Middle	6	1,008	More	7	1,176	Less	4	0,672
4	Ready made part	0.15	Standard part	Middle	5	0,75	Middle	6	0,9	Middle	6	0,9
5	Part assembly	0.06	Open assembly process	Middle	5	0,3	Less	6	0,36	Middle	5	0,3
6	Simple part	0.09	Simplicity	Middle	5	0,45	Middle	6	0,54	Middle	5	0,45
7	Part safety	0.09	Reliability	More	8	0,72	More	8	0,72	Middle	7	0,63
8	User safety	0.21	Safety	More	8	1,68	More	9	1,89	More	8	1,68
∑Wt=1 d: value sum Ad: Weight value sum				∑d1=51 ∑Ad1=6,62			∑d2=59 ∑Ad2=7,602			∑d5=47 ∑Ad5=6,112		

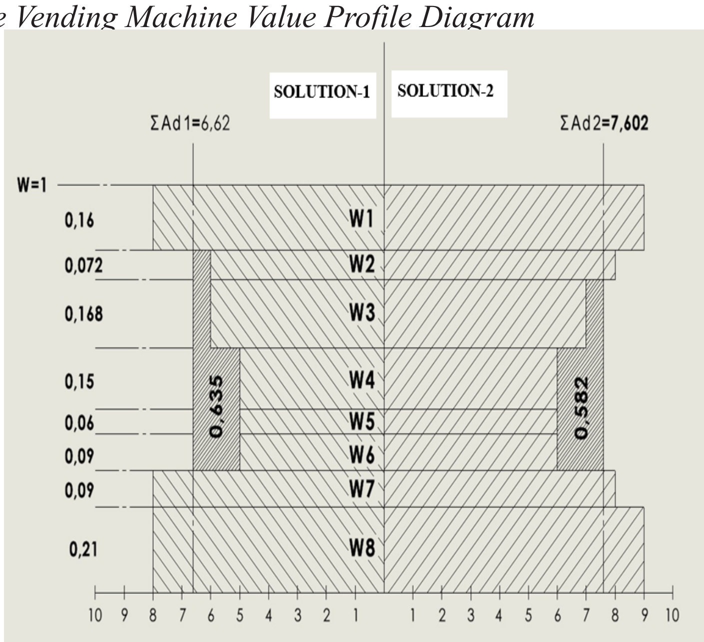
In Table 5, the solutions were evaluated by assigning value grades separately. In this evaluation, the value analysis table n Table 2 was used to quantify the criteria. Being able to rate the weight values well will provide great convenience in finding the most ideal solution. While there are evaluation criteria between 0-10 in the value analysis, according to the VDİ 2225 guide, a more rough evaluation is made between 0-4.

Table 6
Value Analysis Schedule and VDİ 2225 Guide (Mayda, 2007: 119)

Value Calculation			
Value Analysis Chart		**Vdi 2225 Guide**	
Weight	Meaning	Weight	Meaning
0	Impractical Solution	0	Inadequate (Well Below Average)
1	Unsuitable Solution		
2	Weak Solution	1	Middle (Below Average)
3	Intermediate Solution		
4	Suitable Solution	2	Appropriate (Average)
5	Enough Solution		
6	A Good Solution With A Few Shortcomings	3	Good (Above Average)
7	Good Solution		
8	Very Good Solution		
9	Solution in Excess Of Need	4	Very Good (Well Above Average)
10	Ideal Solution		

According to Table 5, the design with the lowest weight value in the evaluation chart is eliminated and a value profile diagram (Figure 12) is drawn for the remaining two conceptual designs shown İn green.

Figure 12
Waste Vending Machine Value Profile Diagram



In the value profile diagram, we have transferred the parameters for the last two conceptual designs as shown in Figure 12. In this diagram, the vertical lengths are given according to the weight values of the measurement criteria. Horizontal lengths represent the values we have given in the solution option for that criterion. Finally, we have shown the sum of the weight values calculated in Table 5 for the solutions with vertical lines. With these vertical lines, we have shown the remaining gap areas in the criteria with less criterion value on that axis with dark coloured hatchng regions. The size of these dark coloured hatching areas expresses the size of the gap for that solution criterion. (Börklü & Erdemir, 2019; Bozdemir & Toktaş, 2001; Doğan,2021,p:67; Mayda & Börklü, 2008; Mayda & Riza Börklü, 2014;Parlar vd.,2017; Şanlier & Börklü,2017; Şekercioğlu, 2019; Yaldiz,2019,p:71) Since the size of the missing areas for Solution-1 is larger than Solution-2, 'Solution-2' conceptual design of waste vending machine was determined as the most ideal conceptual design option as a result of the method.

Results And Discussion

As a result of the research, the conceptual design method we applied showed the solution-2 option for the most ideal design. Accordng to this design, the power unit will be operated by electrical connection. The control unit is computerised. As object recognition technology, the material type will be defined accordng to the density of the material by optimisng weight and volume measurement. Then, the guidance mechanism to be operated with the electrical system will be activated and the material will be transmitted to the warehouse section. The user will be paid as a result of the calculation to be made according to object recognition technology. This process will be notified to the user with the sound effect method. In the production of the machİne, ST 37 sheet metal or carbon fibre composite material will be used mainly in the body and hoppers. Composite materials, especially carbon composites, are extremely resistant to vandalism and impacts outside the cabin. (Kayrıcı & Taser, 2024, ss. 12885-12898) The result will be as shown in Figure 13.

Figure 13
Recovery Vending Machine

Conclusions And Suggestions

As a result, the conceptual design method has evaluated and presented the most ideal solution option for the waste vendİng machine in a systematic way by giving fast results. With this method, our list of requirements is specified n detail. The basic problem is expressed abstractly as a whole function and divided into sub-functions. Solution alternatives have been developed for each function. With the help of the morphological card, solution variants were created by combinng these solution methods appropriately. These design alternatives were eliminated with the help of a selection card and the remaining solutions were evaluated and the last two solution variants were obtaned. These solution variants were discussed in a diagram called value profile diagram and the most ideal design was selected. The most successful design has been reached in all functions by selectİng the solution method in the problem sub-functions that we have handled systematically.

This method provides great convenience to designers as a solution. Selection processes sometimes create big problems for designers and prolong decision-making processes. These processes sometimes extend to the production stages and design changes can be made during production and material and time losses may occur. It will be of great benefit to the designer to be able to handle these processes in detail before starting the design and to solve them in a timely manner. The success of the solution will also benefit the producer organisations by creating positive results in increasing the market share by increasing the customer's orientation to the product in the offer size works. Conceptual design makes a great contribution to designers in this respect. It is a design method that designers should use with importance.

References

Beitz, W., Pahl, G., & Grote, K. (1996). Engineering design: a systematic approach. *Mrs Bulletin*, *71*, 30.

Mayda, M. (2007). Web tabanlı kavramsal tasarım. Gazi University.

Bozbuğa, F. (2018). Yaşlı ve engelliler için merdiven asansörü geliştirme. Gazi University.

Börklü, H. R., & Erdemir, F. (2019). Yeni bir çim biçme makinesinin kavramsal tasarımı. *Düzce Üniversitesi Bilim ve Teknoloji Dergisi*, *7*(2), 15-26. https://doi.org/10.29130/dubited.460036

Şanlier, C. (2019). Kullanıcı odaklı ve doğadan esinlenen yeni bir tasarım işlem modelinin geliştirilmesi. Gazi University.

Şekercioğlu, T. (2019). Kavramsal Tasarım Aşamalarinda Bakımin Yeri ve Önemi. *Mühendis ve Makina*, *60*(694), 67-76.

Bozdemir, M., & Toktaş, İ. (2001). Mekanik Sistemlerin Kavramsal Tasarımina Sistematik Bir Yaklaşım. Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi, 7(2), 165-171.

DOĞAN, G. Havalimanı Yolcu Köprülerinde Kullanılan Uçak Temas.

Mayda, M., & BÖRKLÜ, H. (2008). Yeni bir kavramsal tasarım işlem modeli. TÜBAV Bilim Dergisi, 1(1), 13-25.

Mayda, M., & BÖRKLÜ, H. (2014). Yeni ve İnovatif bir Kavramsal Tasarım İslem Modeli ile Su Filtresi Tasarımı. Gazi University Journal of Science Part C: Design and Technology, 2(1), 169-180.

Parlar, Z., Soybora, E. K., Burhan, M. S., & DAVASLIGİL, S. (2017). Systematic design and design thinking approach for conceptual design process: small household appliance design. Sakarya University Journal of Science, 21(5), 1100-1109.

BÖRKLÜ, H., & ŞANLIER, C. İnovatif Bir Bebek İzleme Cihazinin Kavramsal Tasarımı.

Yaldız, N. (2019). Kavramsal tasarım yaklaşımlarinin İncelenerek yeni bir yaklaşım geliştirilmesi. Pamukkale University

Kayrıcı, M., & Taser, H. H. (2024). Experimental investigation of the effect of fabric wrapping method and autoclave curing on the mechanical and thermal degradation of carbon nanotube doped and undoped carbon composite pipes. *Polymer Composites*. **https://doi.org/10.1002/pc.28675**

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