THE REPUBLIC OF TURKEY
BAHCESEHIR UNIVERSITY

A SOFTWARE DEVELOPMENT FOR THE PROMOTİON OF ENERGY-EFFICIENT HOUSEHOLD APPLİANCES

Master's Thesis

BAHAR MOGHADASI FEREIDANI

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ELECTRICAL AND ELECTRONICAL ENGINEERING

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ABSTRACT

A Software Development for the Promotion of Energy-efficient Household Appliances

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Electrical and Electronics Engineering

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Growing the population and developing technology are causing the residential sector consume the biggest energy consumers and gas emissions in the world. The rapid increase of the energy consumption and prices by appliance has pointed out the lack of energy efficiency in that sector. Therefore, a good understanding of energy efficiency by home appliances is required in order to reduce energy consumption in buildings.

The majority of previews studies in the energy efficiency of buildings have focused more on proposing different systems like smart home systems, scheduling operating systems, energy management systems, smart meters and sensors. Despite the fact that these systems can reduce energy consumption in buildings, but since installation of these systems mostly are expensive and also require internet connections, therefore totally they may not optimally help different types of consumers to reduce their energy consumption in home. On the other hand, they didn't mentioned how to choose the most energy efficient and suitable appliances for different consumers. Therefore in order to guide consumers in this way effectively, we proposed an approach which point out the gap in the previews works to improve energy usage in homes. In another word, this study aims to propose a model which can optimally reduce energy consumption of household appliances through aiding consumers to find out the most suitable energy efficient appliances based on their life style in homes. We have developed software in order to implement our model perfectly and making life easy for different consumers to obtain useful information.

Keywords: Energy Efficiency, Energy Consumption, Household Appliances, Optimization, Software.

ÖZET

Enerji Tasarruflu Ev Aletleri Tanıtımı İçin Bir Yazılım Geliştirmesi

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Elektrik-Elektronik Mühendisliği

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Hızla artan nüfus ve teknolojik gelişmeler konut sektörünün en çok enerji tüketen sektörlerden biri olmasına sebep olmaktadır. Ev aletlerinin enerji tüketimindeki artış, bu sektördeki enerji verimliliğinin eksikliğini göstermektedir. Bu nedenle binalardaki enerji tüketimini azaltmak amacıyla ev aletlerindeki enerji verimliliğinin iyi bir şekilde anlaşılması gerekmektedir.

Binalardaki enerji verimliliği hakkında yapılan önceki araştırmaların çoğunluğu daha çok akıllı ev sistemleri, enerji yönetimi sistemleri, akıllı metre ve sensörler gibi farklı sistemleri sunmaya odaklanmaktadır. Binalardaki enerji tüketimini azaltmalarına rağmen kurulumları pahalı olduğundan insanların büyük bir çoğunluğu bu sistemleri kullanmayı tercih etmemektedir. Ayrıca bu araştırmalar enerji verimi en yüksek ev aletlerinin nasıl seçileceğine de değinmemektedirler. Bu nedenle tüketicilere daha iyi yardımcı olabilmek amacıyla bizim modelimiz enerji verimi en yüksek ev aletlerinin neler olduğunu tüketicilerin hayat stillerine dayanarak sunmaktadır. Bu çalışmadaki temel amacımız ev aletlerinin enerji tüketimini minimuma indirmektir.

Anahtar kelimeler: Enerji Verimliliği, Enerji Tüketimi, Ev Aletleri, Optimizasyon, Yazılım

CONTENTS

FIGURES

ABBREVIATIONS

GUI	:	Graphical user interface
ILP	:	Linear programming
MILP	:	Mixed integer-linear programming

SYMBOLS

Average lifetime of equipment	:	M
Energy consumption per cycle	:	E
Initial price of appliance	:	I
Number of cycles in a week	:	N
Total lifetime cost (TL)	:	C
Unit cost of energy	:	R

1. INTRODUCTION

Growing population, technologies development and modernization of buildings and household appliances afford that residential sector become the biggest energy consumer and also important cause of greenhouse emissions in the world. Therefore, to make a balance between energy consumption and growing population, we have to comprehend the basic and requirements of energy use in buildings in order to find out an optimization model to reduce energy consumption in home and save more energy and also money at the same time. Researching in the field of energy consumption optimization models and energy management approaches in residential sectors made us thinking about what is the real purpose of these models and how they can help consumers to achieve those goals in a beneficially way?!

The high amount of energy consumption has huge effect on environment due to emitting greenhouse emissions, air pollution and global warming. On the other hands, since energy consumption has a close relation with economic, increasing use of energy in buildings directly will cause spending more money on home energy bills and indirectly increasing household appliance's price in the market. Therefore with managing and reducing energy consumption in residential sectors we can help to keep our environmental impacts minimal and save more money.

In another word we can say need of saving energy lead us to focus on the important concept of today's world which is sustainability in order to find out an optimal solution to improve energy consumption in buildings. The main objective of being sustainable is to making a good balance between using and preserving for the needs of today and future through saving energy resources and reducing environmental footprints as the priority of that. That is why researchers believe that energy efficiency is the main solution of sustainability in today's world. In another words, since residential sector has known as the biggest energy consumer in the world, therefore energy efficiency in buildings plays an important role in developing the residential sustainability. But what is energy efficiency in buildings?

In general energy efficiency means how to manage same operations with using less energy. As a result of being more energy efficient we can save more money and energy with minimizing environmental impacts. We can achieve energy efficiency in buildings

through different ways. Despite of choosing suitable windows to avoid wasting energy from home and also installing optimal heating systems, one of the most important factors which have huge effects on energy efficiency in buildings is choosing the efficient household appliances for homes. As we mentioned before growing the population, technologies and also increasing the interests of consumers to buy various models of home appliances has caused rising production of home appliances by manufacturers and as a result of it, increasing the energy consumption in residential sectors. Therefore reducing household appliance's energy consumption is assumed as the main solution toward saving more energy and being energy efficient in home.

Since energy efficiency by household appliances is a significant strategy to save money and energy, so many countries in the recent decades began to implementing more energy efficient plans such as appliance's standards or energy label with strict energy efficiency prescriptions. These approaches have forced manufacturers to produce more efficient productions and encourage consumers to choose these types of appliances.

Importance of energy efficiency of household appliances has caused researchers and Scientifics effort to create and present models which can help reducing energy consumption and save more money for consumers. Although these models have different approaches such as utilizing smart meters, scheduling operations, controlling appliances via networks and etc. but they have provided with the same goals which is energy efficiency and optimization in the buildings.

Significance of energy efficiency and energy management in buildings made us curious to search about this issue and present a model which can help consumers to choose energy efficient appliances in order to reduce their home bills and also save more energy. Although researchers have provided useful and optimized approaches to prevent increasing energy consumption by appliances, but still it is not sufficient to balance wasting energy in residential sectors. That is why we have decided to develop a model for improving energy consumption by household appliances. In another words, lots of varies appliance's models in the market from one side and also lack of information about which specific appliance can be useful for different consumers have made us researching in that topic to find out a model which can optimally reduce energy consumption by appliances. The approach of this model is based on presenting useful information about different appliances to make consumers inform that which types of

appliances are suitable and efficient for them. We have developed our model through suitable software in order to access easily.

This thesis have presented in four chapters. Chapter two deal with previews researches which have done about energy consumption by home appliances and energy efficiency in buildings and describe them as a literature review. Methodology and the software that we have used in this study along with the approach of our model explained in detail in chapter three. In chapter four results of software have shown and finally we have made a conclusion about our model specifically in chapter five.

2. LITERATURE REVIEW

Since reducing energy consumption plays the important role in the sustainability in buildings, in order to find a solution for it and save more energy and money, we should review the different models and approaches based on energy efficiency in buildings to optimize energy consumption. Therefore, in this paragraph we are focusing more on energy efficiency or energy consumption by domestic appliances in home and some approaches to measure this. For example Johanson et al. (2014) presented a model for appraising the behavior of consumers in home in order to calculate residential energy consumption. Later on, they used this model to simulate the energy consumption of residential domestics. There are different approaches focusing on energy consumption in home. Arghira et all. (2012) provided a novel method which can estimate energy consumption for all appliances in building. Their work has three sections. First step is prediction for all appliances energy consumption. Then the second step is estimating the total energy that can consume in home. And last step is making prediction based on households provided. They believed that although predicting of appliance energy consumption for buildings is a difficult work because it is directly related to the consumer's habits, but the result of predicting energy usage of appliance can significantly improve energy managements of grid since residential sector is assumed as an important sector which demands the huge percentage of total electricity. As the numbers of appliances are increasing in the today's market, it is difficult to clarify for each appliance that how much energy they use separately or how many percentage of the total energy consumption based on the energy information that we can see in the monthly bills are related to each appliances. Elbe and Schmautzer (2013) used modern method to obtain the electrical power consumption of each home appliance. they proved that with applying their method in homes, they can informs consumers about energy consumption of each appliance separately that can help them to control their energy usage in home without using different devices like smart meters and etc. On the other hands Vivekananthan, Mishra and Rajashekara (2014) believed that dynamic pricing in present market can effect on the customers behavior in using energy with a raised energy consumption cost. Therefore, because of price variation, customers should control their energy consumption more. They proposed a new technique in Home

Energy Management that helps customers to reduce their energy consumption cost just by controlling their loads. Also de Angelis et all. (2012) showed that with putting restrictions by dynamic pricing through mixed-integer linear programming, we can reduce energy consumption cost and obtain our desire in home energy management. Another approach which can optimally reduce energy consumption by appliance in home is operation scheduling. Household appliance scheduling is a technique which can help consumers with making an optimal plane to operate appliances with the aim of saving more energy in home. Agnetis et all. (2011) pointed this approach and explained that it is hard for users to make a plane for operating appliances due to modification the energy price by time, in order to reduce energy consumption. On the other hand Abrahamse et all. (2005) believed that one of the most effective approaches for decreasing energy demand is informing users about their energy consumption with providing some feedback to them. They said that "based on these insights, the European Commission formulated directive 2012/27/EU on energy efficiency (2012), which states that at least 80% of the households should be equipped with smart meters by 2020". A smart meter is a measurement device that records energy consumption in home and user can be aware of their domestic energy usage costs with using it in order to reduce energy consumption more intentionally. Nguyen (2014) also believed that giving update feedback about user's energy consumption is the important solution to increase energy saving. He developed a mobile application to show user some update energy consumption information from home which work based on smart meter. His aim is to make user aware of his or her energy usage to save energy and also preventing user to use appliance in the peak time energy. Another example of using smart meter can see in the Kavousiana, Rajagopal and Fischer's (2015) article. They offered a new method which can rank energy efficiency of home appliances with using smart meter. They believe that ranking energy efficiency of appliances can give important idea to the user to reduce their energy consumption in buildings.

Since most of the models which have provided about energy efficiency in buildings by researchers have aim of minimizing energy consumption or maximizing energy saving, we can point out the importance of optimization method to reach that goal perfectly. Therefore in the second paragraph we are focusing more on optimization methods which have used in different topics and how this approach can minimize or maximize

specific objective. For example, Vergnano et all. (2012) presented a novel method for robotic manufacturing systems which optimizes energy consumption of them. The objective function for this optimization problem is minimizing total energy consumption. Long Duy Ha et all. (2006) used a control algorithm with aim of solving the home energy management problem and one of their objectives was minimizing the total energy cost. They solved synthetic optimization problems related to their purpose with using Tabu search.

Generally optimization is the arrangement concepts which want to solve a system that has aim of minimize or maximize a specific value. Also some of the researchers use computational optimization which is a method that work based on some steps like implementing and testing a special algorithm on the some optimization problems. For example, Sadegheih (2010) applied a genetic algorithm on the problem of power transmission networks development minimum price for carbon emission trading programs to find a solution for it. Some authors like Cai et all. (2009) have applied interval linear programming (ILP) and mixed integer-linear programming (MILP) techniques to optimize problems with targeting to minimized system cost, maximized system reliability and energy security.

Until now we explained the optimization methods in different topics and also the importance of energy efficiency in buildings and reviewed the most recently developed approaches toward enhancing energy usage in homes like the idea of smart control technologies such as smart meters or smart sensors and home energy management systems and etc. In order to be more specific toward appliance energy consumption in home, in this paragraph we are focusing more on energy consumption optimization by domestic appliances in buildings. Different approaches have provided for this particular topic. For example, Zhang et all. (2009) presented a power conservation system based on optimization method for buildings. The energy consumption optimization model which has used in this study is the basis of this article and had aim to obtain minimized level of the user's energy consumption in home. This system contained 2 sectors. First one is about controlling and observing the appliances by user and second on is remote controlling station. The remote section is working based on the optimization model of this study. This section according to the conservation requirement, previews records of consumer's energy consumption and their behaviors on using energy calculates the

current orders which come from consumers. After this calculation finished, those orders will use in the user controller in order to decide whether to allow a consumer to operate a specific device or not. They used binary programming software in order to develop their optimization model. From this study we can understand the optimization model which has used in this study, simulate consumer's energy consumption habits with objective of optimizing appliance energy usage pattern or minimizing energy consumption of appliances in building. Although this system can reduce energy usage in home but one of the problem of this model is about weekend period. Since in the weekend consumer's energy consumption habits are totally uncertain and changeable, therefore the energy consumption pattern of appliance during this time has huge difference with the consumption pattern in weekdays and it will cause a wrong calculation and also wrong decision making in remote section. So in order to prevent this mistake system should allow the consumers to use appliances as much as they want in the weekend and obviously the final result of this system cannot be reliable.

As we have explained before some researchers believed that scheduling the operations in home is one of the most efficient way in demand side management in order to avoid operating appliances in the peak load time. For example, Mohsenian-Rad et al. (2010) made scheduling for energy consumption of different appliances with using optimization technologies with objective of reducing the value of peak to average power ratio to the minimum level. The most popular optimization techniques that researchers choose to schedule energy consumption of appliances are mixed integer linear programming (MILP) and linear programming (ILP). If there is huge number of appliances it would be better and more flexible to use linear programming to schedule appliance's operation. For example, Sherif, Ziming and Lambotharan (2014) developed a mathematical optimization for household appliances to make a scheduling for them. Their aim was to apply linear programming optimization techniques into the 30 homes which included different household appliances with ability to change their power and time, in order to decrease peak to average power ratio value of total energy consumption. The optimization result has showed that these types of appliances can produce consumption peak in the afternoon time around 4 pm which is not our desire. The linear programming method can decrease the consumption peak from these appliances from 6 to 8 pm. Furthermore some researchers like Zhu et al. (2011)

enhanced planning the operations with proposing different approach to optimizing the scheduling the appliances. They have used mixed integer linear programming for that purpose instead of using linear programming, in order to increase number of problems which can add to the models and also extension variation of variables like integer, binary and etc. Although scheduling household appliances can reduce energy consumption in homes but because of unpredictable energy consumption behavior of consumers due to busy and unplanned life style of most of them, it cannot play an efficient role in optimization of energy consumption in buildings. That is why some authors like Du and Lu (2011) presented an obligation algorithm for appliances which schedules home appliances based on prediction of consumption and price with respect to the consumer's benefits and also aim on minimizing payments. They believed that since users are not expert in scheduling the appliances and also economic, therefore an automatic scheduling system which just needs cares and fallowness from user to run efficiently can solve problem of scheduling appliances. On another hands, Lin, Tsai and Chen (2011) suggested that with monitoring energy consumption in buildings we can significantly reduce our energy consumption. They believe when all the household appliances are operating in efficient way, it will finally make balance for total consumption and also save energy as a result. In order to implement their idea they used a system for monitoring performance of appliances which applies an optimization algorithms and fuzzy classifier to recognize whether appliances are energizing or not.

With review of these studies in energy consumption optimization of domestic appliances we can understand the most novel approaches toward reducing energy usage in homes. Although most of them can efficiently save energy but we can notice some problems out of them. For example as we have explained before so many researchers believe that new technologies like smart meters, energy management systems, smart sensors and scheduling operations recently play the important role in managing energy between home and smart grid and can significantly save energy. Lu, Wang and Shan (2015) believe despite of taking efficient results from these devices, still there are some communication problems in order to send and receive data between smart grid and household appliances which can cause some turbulence for those approaches. Furthermore, due to the internet capacity problems and also high installation price of

those systems it may not be possible for all the consumers to install these models in their homes.

On the other hands, in most of those studies researchers applied their system on a home which they assumed it contained some energy efficient appliances but since there are lots of energy efficient appliances models in the market how consumers can choose the most suitable efficient appliances based on their life style?

Lack of studies and awareness in choosing proper energy-efficient home appliances for user encouraged us to think about creating a model which can simply give useful information about home appliances to the consumers and guide them to choose the most suitable appliances based on their life style.

3. DATA AND METHOD

The review of literature has provided the importance of research in optimization of energy consumption in residential sectors and made us curious to find out how optimally we can reduce energy consumption by household appliance. What does energy-efficient appliance exactly mean and how we can categorize an appliance as an energy efficient device? Will changing home appliances make enormous impact on energy consumption by user? In this chapter we are seeking to find out best answer for these questions.

The methodological realization and the procedures used to provide an evaluation and scientific justification of the results and findings are discussed within this chapter. We started by discussing issues regarding the purpose of study, and then moved on to the details of research design and software development. After that we continued with designing our instruments and then discussing about the data collection method. At the end, algorithm procedures and some of the techniques used for data analysis have introduced.

3.1 PURPUS OF THE STUDY

With growing the population in the world, we are facing with increase and even in some point excess of domestic appliances production which cause increase energy consumption in residential sector and also environmental impacts growth as a result of that. In order to reduce this growing of energy usage researchers provided so many approaches and models. As we mentioned before in literature review there are several studies which have aims to optimize and reduce energy consumption in homes. Smart homes energy management systems, smart meters, monitoring energy consumption of appliance, scheduling appliance operations and etc. are some of the most important approaches that help users to save energy. All of these approaches are providing different models for users with almost same goals. Moreover, manufacturers look into producing more energy-efficient appliances.

With review the details of the recent studies about optimization of energy consumption, we can understand that in most of those studies, researchers with simulating user's

energy consumption path want to propose an optimized model which improve user's energy consumption more efficiently. Although these approaches improve user's energy consumption but still there is some points missing in those studies which can help to save more energy by home appliance. If we look again in those studies we will discover that in order to simulate user's energy consumption behavior almost all of the researchers implemented their models on a home with its appliances. But before applying those models we can ask some questions like which types of appliance we should have in home to be more energy-efficient? How we can choose and be sure our appliance will reduce our energy consumption in home? Although researchers suggest users to use more energy-efficient products but they didn't make a clear statement on telling users how to choose and which types of specific appliance they need in home to be more efficient?!

Lack of awareness in choosing proper energy-efficient home appliances for user leaded us to create and develop an optimized model that promotes energy efficient home appliances with respect to the user's life style and implement it to help users find out the suitable cost and energy-efficient products in order to save more energy and paying less. In another word, this model will lead to optimally energy consumption reduction by house equipment.

3.2 RESEARCH DESIGN

A research design is actually a plan which makes requirement steps toward data collection and analyzing information in a way to fulfill the purpose of the study perfectly. Parahoo (1997) describes a research design as "a plan that describes how, when and where data are to be collected and analyzed". A research design should include a sufficient description of the research questions, purpose of study and methodology which have chosen for collecting data and examining them correctly. Since the purpose of this project is reducing user's energy consumption and total costs of them by choosing suitable energy efficient appliances, to develop and employ the optimized models and to obtain our desired result we have to use some mathematical or computational approach. Therefore, in this study quantitative methodology approach

have used to provide a measurement model to optimize energy consumption and use statistical analysis to determine the results. Burns and Grove (1993) define quantitative research as a formal, objective, systematic process to describe and test relationships and examine cause and effect interactions among variables.

In this study to structure our model correctly we need to focus on which energy efficient types of appliances do user need to pay less money regarding energy consumption in home and also which characteristic should appliances have in order to help user to save more energy in home? Therefore a good understanding of user's life style and also appliance's characteristics are required, since they play important role in design and organize our model structure. In another word, with finding out the relationships between energy efficient appliances, user life style and our goal which is energy consumption optimization, we can define a proper scenario for our model and design it efficiently.

Since we want our model work according to the user's life style, gathering some information of user's habits in using energy is the basic task of the model. This can be done through a proper questionnaire, because it often seems a logical and easy option as a way of collecting information from users in order to estimate their energy consumption habits. Also to calculate and evaluate some variables regarding to the energy consumption and its price we need to collect some sort of quantitative data. Consequently we will use those data and user's information as an input to the optimization algorithm in order to find out which appliances are more energy-efficient for specific user.

In order to design and implement our model efficiently we have used software development methodology in this study to provide suitable communication between questionnaire, quantitative data collection, mathematical algorithm and operations to obtain desired result easily. In the next section we will describe what exactly software development methodology is and how we are going to use it in our study.

In order to formulate and test working assumptions about a process of our software implementation we need to collect required data for our model. Data collection methods can plainly help us to collect our desire information which is related to the objects of our study. For our study purpose we have used primary and secondary data collection method.

Secondary data collection comprises those information that other researchers have approved and provided them before as books, articles, reviews, reports or some official websites. In this study the secondary data collected from records of the companies through their websites. But primary data collection is those data which researchers are collecting them in their study by themselves to examine whether they are correct or not. In our study primary data will collect from our software. With combination of these two techniques we can examine our model optimally.

3.3 SOFTWARE DEVELOPMENT

Software development is the collection of some software which uses to build the new and desire program for someone which needs to complete some steps to be ready. These steps contain the objectives of creating this new software, preparing the design of our desire, deciding about which other software we need to use and also clarifying the way that we want to code our new software.

Therefore, in order to develop new software we should decide about purpose, requirements, design, applications, prototyping and sources. Here we have listed software development steps shortly, in order to clarify how we can build new software.

1. Software requirement (objective)
2. Software requirements analyzing
3. Software design
4. Programming (implementation)
5. Testing
6. Maintenance

First step in the creating new software is about highlighting the objectives of building new software. We made this step clear before as we mentioned that the main aim of this project is to optimize user's energy consumption by home appliance. In this project we want to reach this goal by promoting energy efficient appliances to the user.

Next step is analyzing user information needs. Obviously after defining objectives of our new software we should search for different conditions and situations which help us reaching our goals and analyze them correctly to fulfill our desire through this software.

In this project in order to find out and analyze requirement information for users to choose suitable energy-efficient appliances we need to answer some questions related to the appliance such as what does suitable energy efficient appliance means? Which quality makes a specific appliance more efficient? Which energy-efficient appliance is more suitable for a user and how we can choose the best specific energy-efficient appliance for a user? And also some questions related to the user's life style such as how many persons are going to use the specific appliance? Or how much the user wants to pay for the specific appliance? To be able to answer these questions accurately first of all we should clarify our model's approach in order to define a specific suitable energy efficient appliance.

In our study we define a suitable energy efficient appliance for a specific user not just because of using less energy to provide the same service but also for being more appropriate to the user's life style. In another word, a suitable energy efficient appliance is a device which is best fit for the user's budget and uses less energy than other relevant devices with respect to the energy rate of it and also has a proper capacity proper for the family's members that want to use it. Therefore, energy consumption, energy rate, price and capacity are the essential characteristics of each household appliance that we should consider them in our optimization model. In this project we have specified another important concept which is based on energy price to obtain our desired result more accurate. It has described as a total lifetime cost of each appliance in Turkish Lira and it includes initial price of appliance plus energy usage cost during lifetime of that appliance. With utilizing this concept we can assess appliance's operation better. On the other hand, in our model number of people who want to use appliance, number of time that they approximately want to use it and budget of user for each appliance are also other important characteristics. The reason of this is clear. For example for a family with 3 members it is just wasting energy and money if they buy a washing machine which is designed for 6 persons. With describing which aspects of user's life style and appliances are needed in order to fulfill our project goals we are can design our model correctly.

The design step in software development is about how our new software should create and describes desired features and operations in detail. For designing our model in detail, we need to use all information that we found from analyzing user's behavior and

appliance's characteristics to define our software's desired features and functions. Software design is an important step because designing essential functions and features will give a basic form and fundamental structure to our software and in order to design it more efficient we need to take a precise decision about how to use analyzed information and which features and functions exactly this software needs?

As we mentioned before we need some information about user, so in order to collect all necessary information of user we can use some type of questionnaire. Therefore, we need to design a questionnaire with proper questions based on what we want to know from user's life style. Also, to utilize appliance's technical data in our project advantageous we should collect and store them into some types of databases. A database is a tool for collecting and organizing information that have ability to store large number of information about people, products, orders, or anything else. This ability is exactly what we want for our data. Consequently, we need to combine and analyze these data in order to obtain our desired result with utilizing a mathematical algorithm. So we can say a proper questionnaire, databases and mathematical optimization algorithm are the fundamental features of our software that we need to design them thoroughly. However, perfect designing of the software is not just about clarifying which elements should consider in the project, also is about how to make a good configuration for software in terms of required design elements in orders to make a desired relevance between user and software . That is why we have chosen to design our software based on user interface design approach to fulfill our goal perfectly.

User interface is a visible section of program which designed for all users to have a better and easy communication with software. The best user interface has the easiest and also efficient design.

After designing step our model is ready to implement. Implementation is one of the important steps in the software development because engineers prepare and write the code for the project in order to run correctly. This is the time to decide which programing language is the best option for implementing of our model. In this project we have used 2 software in order to create, develop and implement our model optimally. The first software that will create and store our databases and fill them with our required data is SQL Server Management Studio and Microsoft visual C# is the

second software that we have used to implement our questionnaire and main algorithm. In the following sections we will discuss these two software in detail.

After coding the model in order to check if our software is error free and can run completely we can start to test it. During testing the software whatever errors appear can fix. After this step our software development process has done and it is ready to use. Finally, after the first release of our new software we should check it to update and fix errors frequently.

3.4 INSTRUMENTS

Instruments mention whatever sources we have used to collect data like interview, questionnaires, tests and etc. Or shortly it describes as a devise used to collect data. Until now we have explained our strategies and theoretical concepts and this is the time to describe how we should implement our research process to complete our model.
As we want to understand user life style better, collecting some information through a proper questionnaire is the first important step of developing our desired model. This questionnaire is aimed at allowing our method not only to collect some data for calculation with respect to user's life style - in terms of variables - but also to estimate user's path in using energy in daily life. On the other hand, as we mentioned before to calculate usage energy price of each appliances and some other variables in order to find out and suggest the numbers of most energy efficient devices to the user we need to use database method to collect and store some technical details about those devices. Those information will use later as an input in the main algorithm to obtain the result. Therefore, the instruments of this research study include the related questionnaire and databases. We will discuss creating of those instruments in detail.

3.4.1 Database

Database is invisible section of a computer which is prepared to collect data in an organized order and a program can copy or use selected pieces of those_information from database easily. One of the greatest benefits of using databases is that data can be shared or secured among users or applications. This feature makes ways easy to use collected data of databases in another software. There are two different types of

database which are physical and electronic. The aim of creating a database is to collecting, storing, managing and sharing data securely.

In order to access to the database and use data of it we have to use database management system.

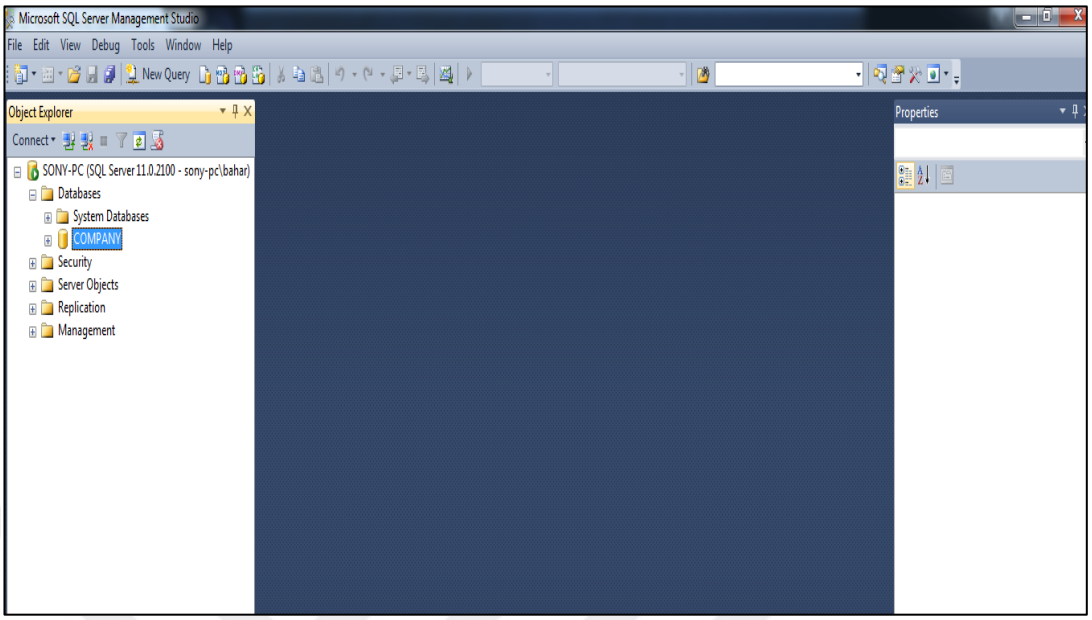
This system is an interface to allow us select or enter some information into the database. Some of the popular database management systems are MySQL, IBM DB2, Postgre SQL, Oracle, Microsoft SQL Server and Sybase. In this project we have used SQL management studio to create our databases. In the next section we will talk about SQL management studio software and using it in order to create our databases in detail.

3.4.2 SQL Management Studio:

SQL (Structured Query Language) is software which has designed to collect, manage, store and query data in databases. We can refer this software as a standard language for managing the database perfectly. In order to do any operation in SQL we have to run a query. Queries define as command in SQL which make it simple to update, delete, select and insert our stored data. A database may contain some items called tables which have designed to store data in it. Tables can recognize by their specific names and are include some rows and columns. Columns as well should have specific name and data type and etc. Rows basically store records or information for the columns. With this brief explanation about SQL software we are ready to use it in order to create our databases.

In this project we have used SQL management studio version 2012. After opening SQL and connecting to the database engine server type we can create our database in that server.

Figure 3.1: SQL Management Studio



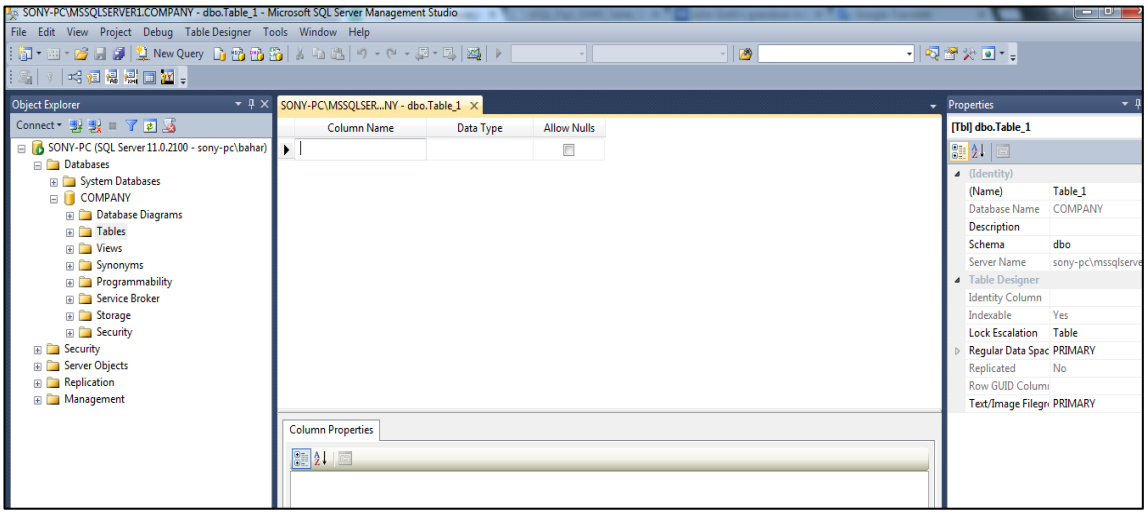
As it can be seen here we created our database and named it COMPANY and it bellows to that server which we connected before. Next step is design our tables in database for filling it with required data but before this step we should make it clear which information we are looking for to collect? What data type will be stored in the tables and how many rows and columns should they have?! As we mentioned before these databases are designed to store our appliances information. This information refers to technical aspect of household appliances. In this study we have decided to choose just washing machine and refrigerator as an example of all home appliances to test and implement our software with them. Also we have used technical information of these 2 appliances from 3 different Companies as an example. Here we will explain how to find out requirements information for one Company. First step is finding the official website of that specific company and opening the home products section and then choose household products.

In that section after choosing country we can choose whatever appliance we are looking for. As an example we choose washing machine. Next step is finding out some technical details such as energy consumption and rate, price and capacity of all the models of washing machines and write them separately in the excel file. We should do the same steps for another brand and also another appliance.

Our primary data collection which has been arranged as a table style in excel format includes information of each washing machines in different rows and each columns in order from left to right represent Company name, appliance model, appliance price, energy consumption per year, capacity and energy rate. Total lifetime cost (TL) column is empty yet and in the next step will fill with correct data. We will done collecting appliances information with making another excel table with same row and column style for refrigerator. After completing this part our required data for this study are ready and this is the time to transfer our data to the database which we designed before. Therefore to be able to transfer these data first we need to design some suitable tables in our database.

After clarifying what data we are going to store we can implement a SQL table by using SQL Server Management Studio Table Designer which is an easy-to-use interface for defining the various components that go into a table's configuration. To launch SQL Server Management Studio Table Designer, after connecting to a SQL Server instance, we should extend the databases node and then extend our database which is COMPANY to add the table. Once we extend our target database, click the Tables name and then click New Table. This launches Table Designer in its own window, as shown in Figure 3.3.

Figure 3.2: Creating table in SQL

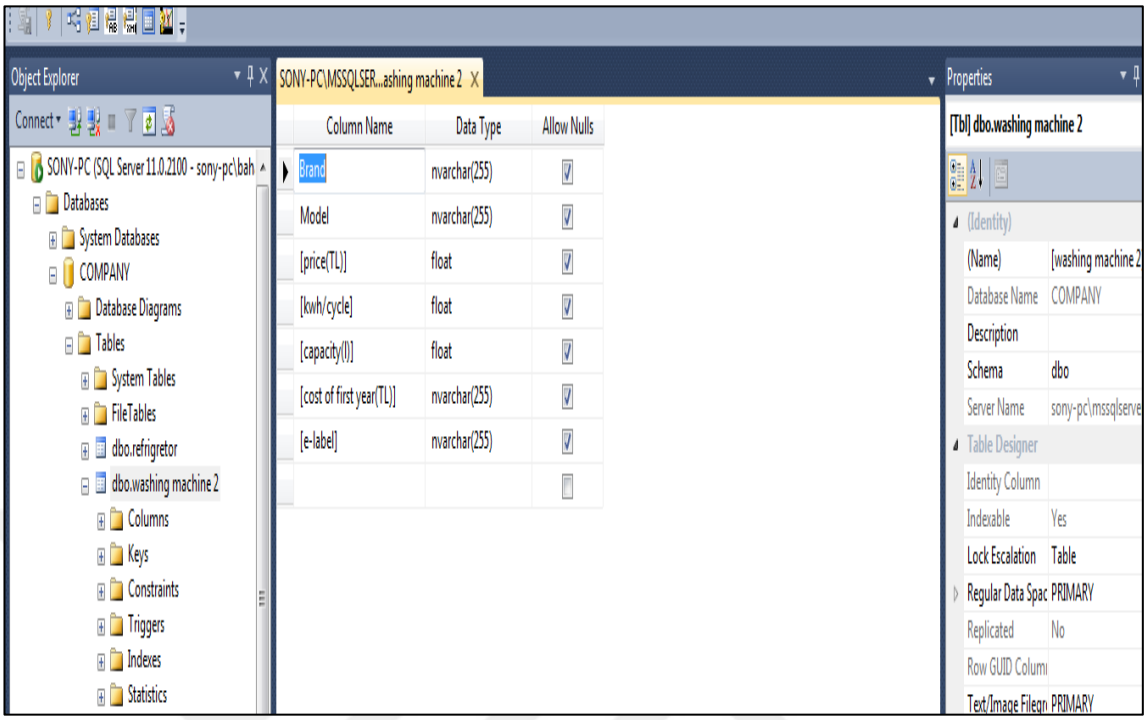


SQL Server Management Studio Table Designer is the center panel that's divided into two panes. We should define our initial columns in the top pane, and we configure additional properties for each column in the bottom pane. The properties displayed in the bottom pane are associated with the column selected in the top pane. Because we have not yet defined any columns, no properties appear in the bottom pane. We can put a name for our table as we want in properties. For example in this study we have named our tables according to appliance's data what are going to store there.

Now let's return to the SQL Server Management Studio Table Designer window and start adding our columns. The first one is Brand, which is configured with the nvarchar (255) data type. For the data type, select nvarchar (255) and then deselect the Allow Nulls option. (The Allow Nulls option is selected by default.)

When you add a column to the top grid, the bottom panel displays the column's properties. The Name, Allow Nulls and Data Type properties are repeated in the lower pane. Next column is model which has again nvarchar (255) data type. After that column, [price(TL)] that represents price of appliance with float data type, [Kwh/cycle] that represents how many kilo watt hours energy per cycle this appliance will use with float data type, [capacity(L)] represents capacity of appliance again with float data type, [Total lifetime cost (TL)] that represents total energy usage cost of appliance in its lifetime with varchars (255) data type and [e-label] represents class of energy in an appliance with nvarchar (255) data type. Here in figure 3.3 we have shown all the column's name and types of them required for our table which is creating for our washing machine's data. So after putting name for each column and select types of them, we will finish designing our table with saving all of these setting in our database. We should do same steps to create another table for our refrigerator's data.

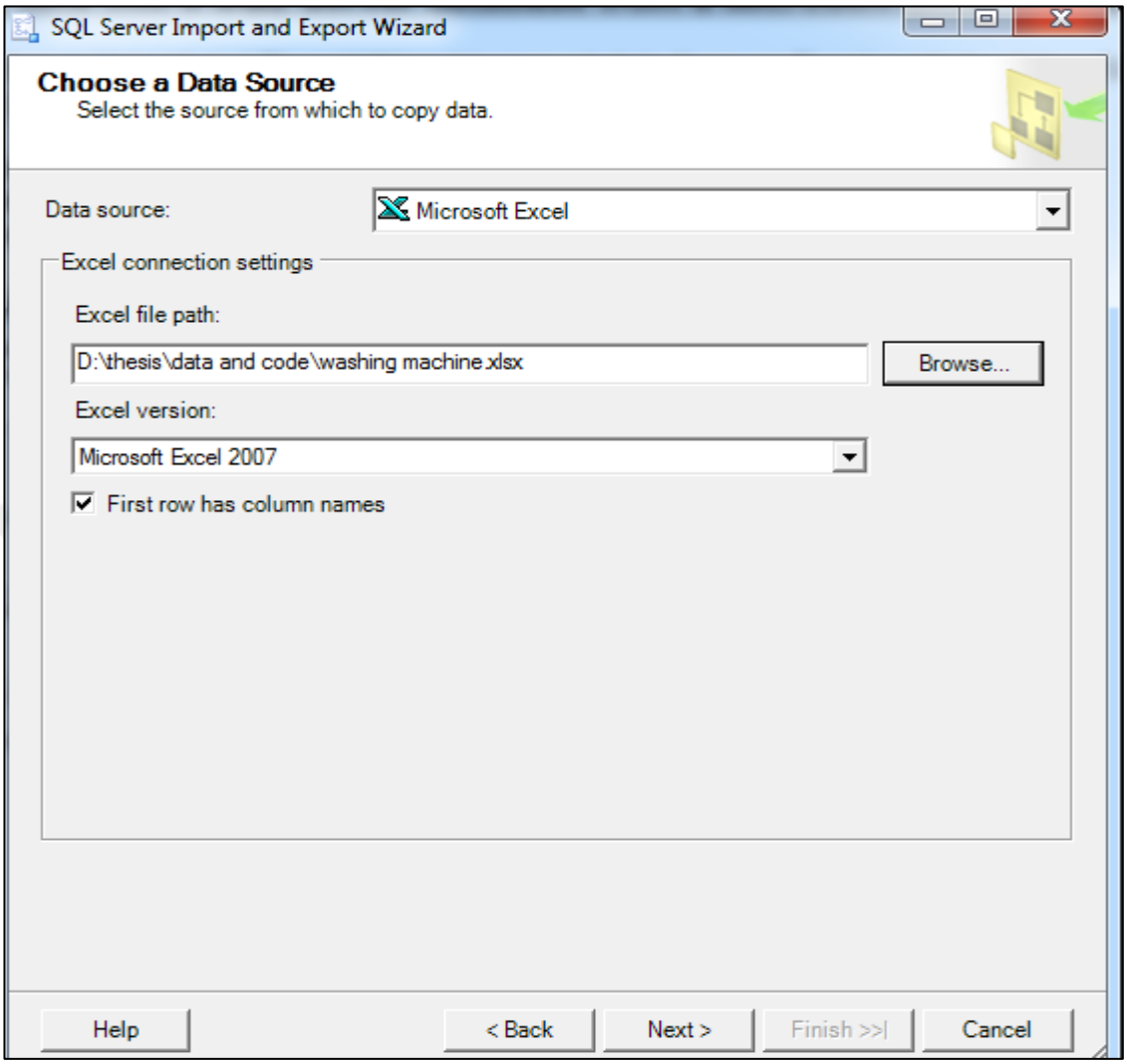
Figure 3.3: Final version of washing machine table



After creating suitable tables this is the right time to transfer collected data of our appliances to these tables. This will be done easily through software Import and Export Data (32-bit).

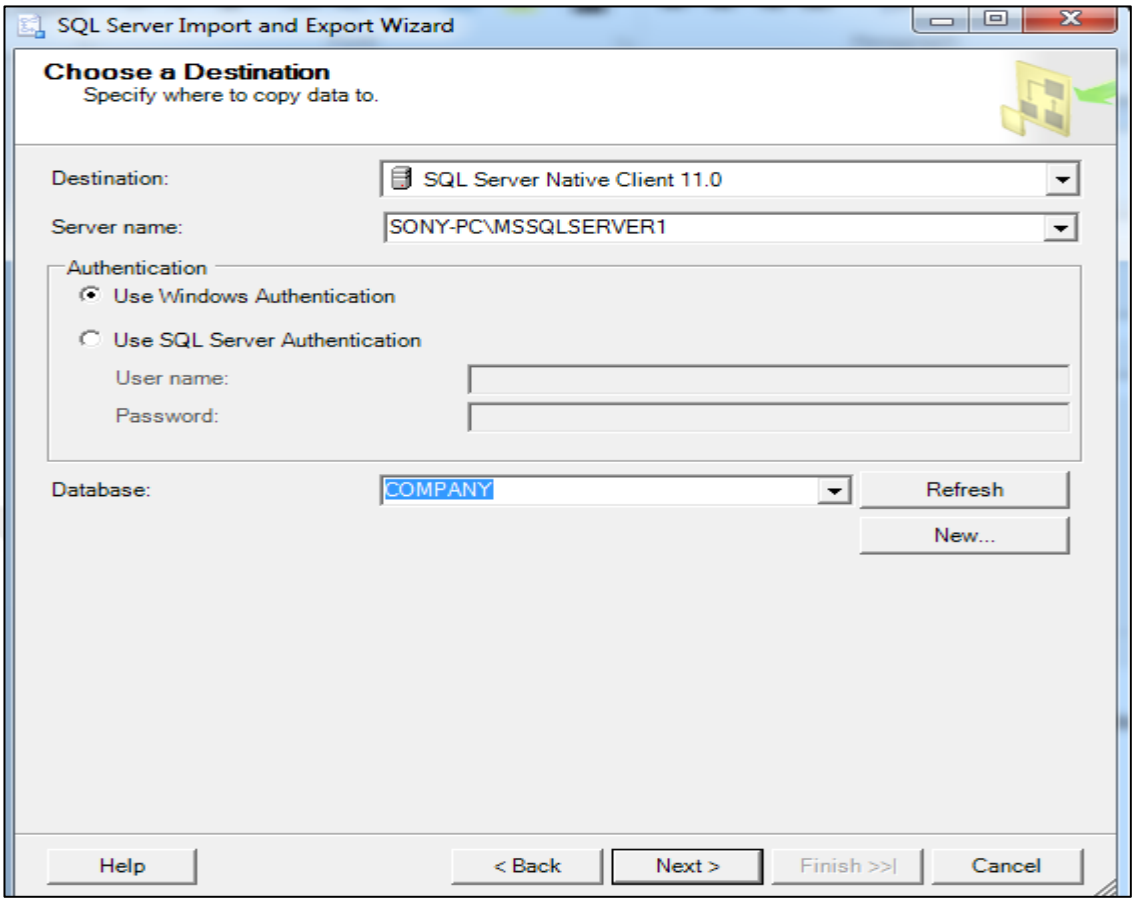
SQL Server 2012 provides different approaches to transfer information completely between SQL databases and Excel documents. The SQL Server Import and Export Wizard offer the simplest method to create a SQL Server Integration Services (SSIS) package that copies data from a source to a destination. We can use SSIS to build extraction, transformation and load (ETL) packages and to quickly create packages for moving data between Microsoft Excel worksheets and SQL Server databases. To Import data into a SQL Server database from a Microsoft Excel worksheet we should open this software and choose Microsoft Excel, Specify the path of the Excel file from which we are importing data and also version of our Excel file.

Figure 3.4: SQL Server Wizard first page



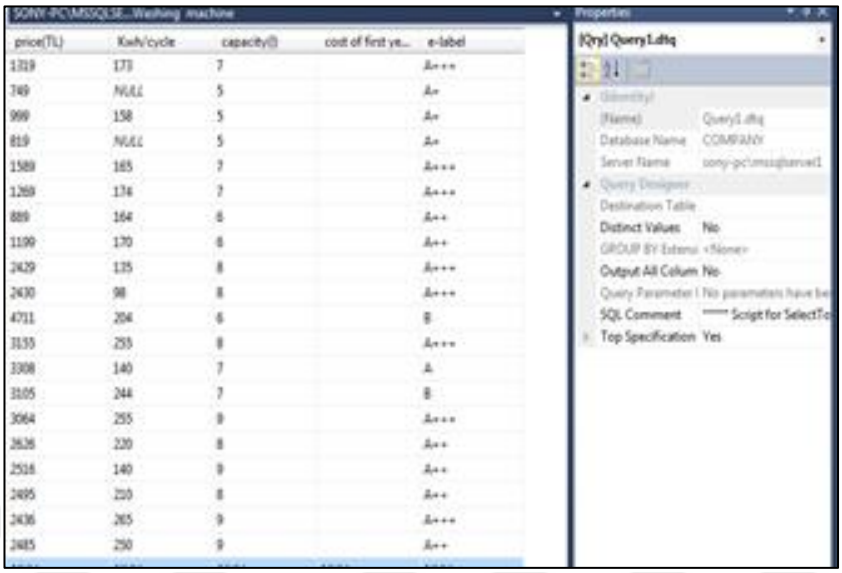
With clicking next we will go to choose destination. After choosing destination, server name and the desired database we can click next and wait for transferring data from Microsoft Excel to SQL database.

Figure 3.5: SQL Server Wizard second page



After completing these steps for both Excel files we can open SQL Management Studio and check our tables.

Figure 3.6: Washing machine table after transferring data in SQL



So as it has shown in figure 3.6 we have transferred our washing machine's data to the COMPANY's table correctly. With saving all the transferred data in our database we almost have done storing our data. As you can see in this figure, total lifetime cost (TL) column is still empty. In order to fill this column we should do some mathematic operations according to our model.

As we mentioned before in our study we will calculate total lifetime cost of energy usage for all the appliances separately. This cost includes initial price plus energy usage price of an appliance its lifetime in Turkish Lira. In order to calculate this cost we defined C as a Total lifetime cost (TL), I as initial price of appliance, N as the number of cycles that user approximately will use this appliance in a week, R as unit cost of energy and E as energy consumption per cycle. The equation is this:

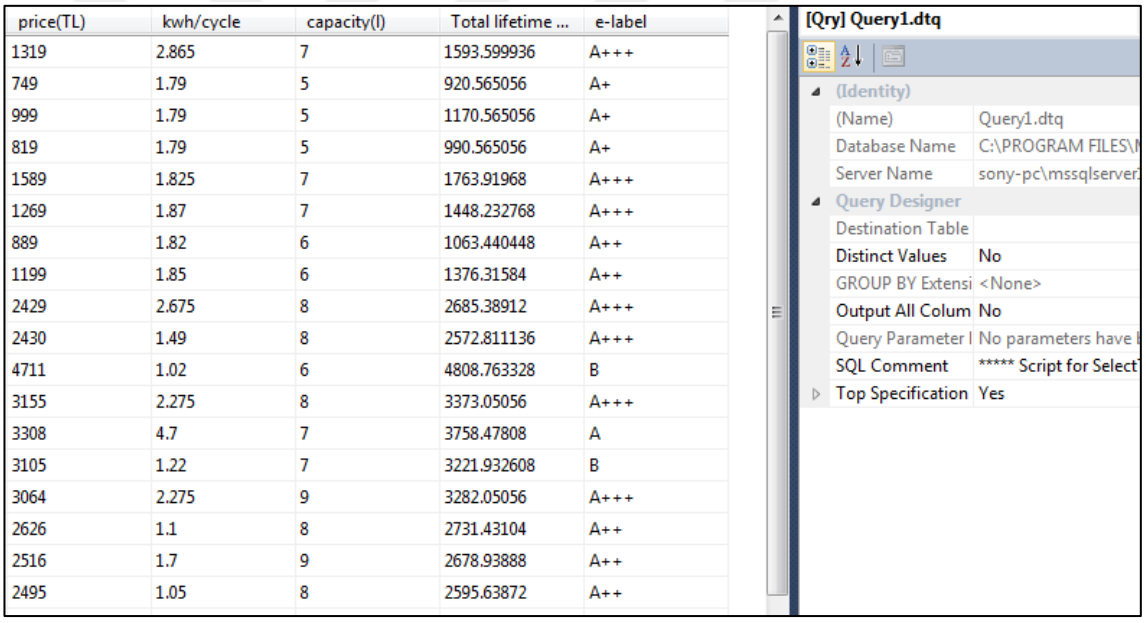
$$\mathrm{C} = I + (E * N * R * 52) * (\sum_{k=0}^{M} (1/1.1)^k) \qquad (3.1)$$

In this equation, 52 is the number of weeks in a year and M is average lifetime of equipment and constant. The result of this equation is an approximation since no one can exactly say how many times he/she will use appliance in a year. Therefore in this study we have denied an approach that estimate this cost with categorized N into 3 groups according to the user's habits. In the first group N is equal to 1 which represents types of users that operate appliance not so much in a week. In the second group N is

equal to 3 which represent types of users that operate appliance sometimes in a week. In the last group N is equal to 7 which represent types of users that use appliance almost every day in a week. With this considerations and also other table's information we can calculate total lifetime cost for each categories. Therefore in our study for some types of appliances that we are not using it like refrigerator continually in home, for example washing machine we should have 3 stored tables with same column's data just different information for the total lifetime cost's column.

After this organization, with writing a proper query to calculate this equation we can fill total lifetime cost's column easily. Here we have shown part of the completed table of first category as an example.

Figure 3.7: Washing machine completed table in SQL



price(TL)	kwh/cycle	capacity(l)	Total lifetime ...	e-label
1319	2.865	7	1593.599936	A+++
749	1.79	5	920.565056	A+
999	1.79	5	1170.565056	A+
819	1.79	5	990.565056	A+
1589	1.825	7	1763.91968	A+++
1269	1.87	7	1448.232768	A+++
889	1.82	6	1063.440448	A++
1199	1.85	6	1376.31584	A++
2429	2.675	8	2685.38912	A+++
2430	1.49	8	2572.811136	A+++
4711	1.02	6	4808.763328	B
3155	2.275	8	3373.05056	A+++
3308	4.7	7	3758.47808	A
3105	1.22	7	3221.932608	B
3064	2.275	9	3282.05056	A+++
2626	1.1	8	2731.43104	A++
2516	1.7	9	2678.93888	A++
2495	1.05	8	2595.63872	A++

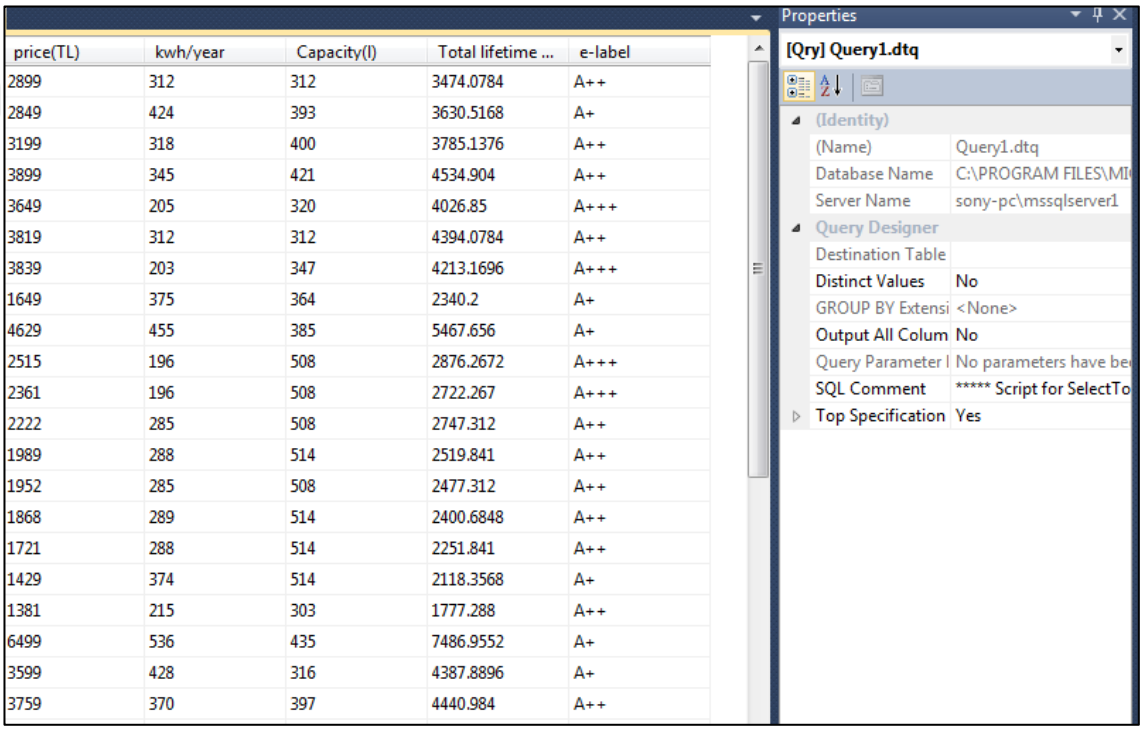
But our model's approach for refrigerator is different. Because refrigerator is operating nonstop in home, so we don't have variable N in the definition of total lifetime cost equation. Therefore we have just one table of data for refrigerator.

This equation for refrigerator can be defined as below:

$$C = I + (E * R) * (\sum_{k=0}^{M} (1/1.1)^k) \quad (3.2)$$

After completing implementation of related query for column of cost of first year based on that equation, our refrigerator's table is ready and we will finish organizing and storing all data of washing machine and refrigerator that we need to use in our study. Here we have shown refrigerator completed table.

Figure 3.8: Refrigerator completed table in SQL



price(TL)	kwh/year	Capacity(l)	Total lifetime ...	e-label
2899	312	312	3474.0784	A++
2849	424	393	3630.5168	A+
3199	318	400	3785.1376	A++
3899	345	421	4534.904	A++
3649	205	320	4026.85	A+++
3819	312	312	4394.0784	A++
3839	203	347	4213.1696	A+++
1649	375	364	2340.2	A+
4629	455	385	5467.656	A+
2515	196	508	2876.2672	A+++
2361	196	508	2722.267	A+++
2222	285	508	2747.312	A++
1989	288	514	2519.841	A++
1952	285	508	2477.312	A++
1868	289	514	2400.6848	A++
1721	288	514	2251.841	A++
1429	374	514	2118.3568	A+
1381	215	303	1777.288	A++
6499	536	435	7486.9552	A+
3599	428	316	4387.8896	A+
3759	370	397	4440.984	A++

With preparing our database we can go further to design our questionnaire. Next section is about design and preparing the questionnaire we want to use in this study.

3.4.3 Questionnaire

A questionnaire can define as a form which includes different types of questions and has aim to collect some details from different users. Questionnaires normally offer through email, interviews, phone calls and etc. In this study we have designed and implemented our questionnaire through the software that we want to develop in order to

get information from it more easily and then analyze them more efficiently. First step in this approach is planning our questionnaire.

In order to plan and develop a questionnaire we need to define our objective first. It means we should explain exactly what we are looking from it and how we are going to use the data to answer our questions. We have clarified before that our questionnaire's main objective in this study is collecting required information from user's life style. And also we have explained that in order to reach this goal, which types of information we need to know. Numbers of people that want to use device, number of time that using it and also budget of user are the most important information that we need to know in this study. So we should prepare our questions based on these items. As we said before we have designed our questionnaire through the software that we want to develop which is Microsoft Visual Studio C#. Here we will explain how to design and develop it with C#.

3.4.4 Microsoft Visual Studio C#

C# is a Microsoft designed programming language which has created to build different types of applications that run under .NET Framework. We can say C# is such a flexible, easy to run and object-oriented language. Visual Studio with all the features like compilers, debuggers, code temples, editors, project designers and different tools help and support Visual C#.

Previously we mentioned that we want to develop user interface software to implement our main algorithm in order to calculate and analyze our required data using Visual C#. Therefore to send the required data collection to our algorithm efficiently, it would be good idea to develop our questionnaire in order to collect and prepare required data also utilizing this software because of professional communication features that this software has. Here we will explain how to design our questionnaire as the first step of developing our software in Visual C#.

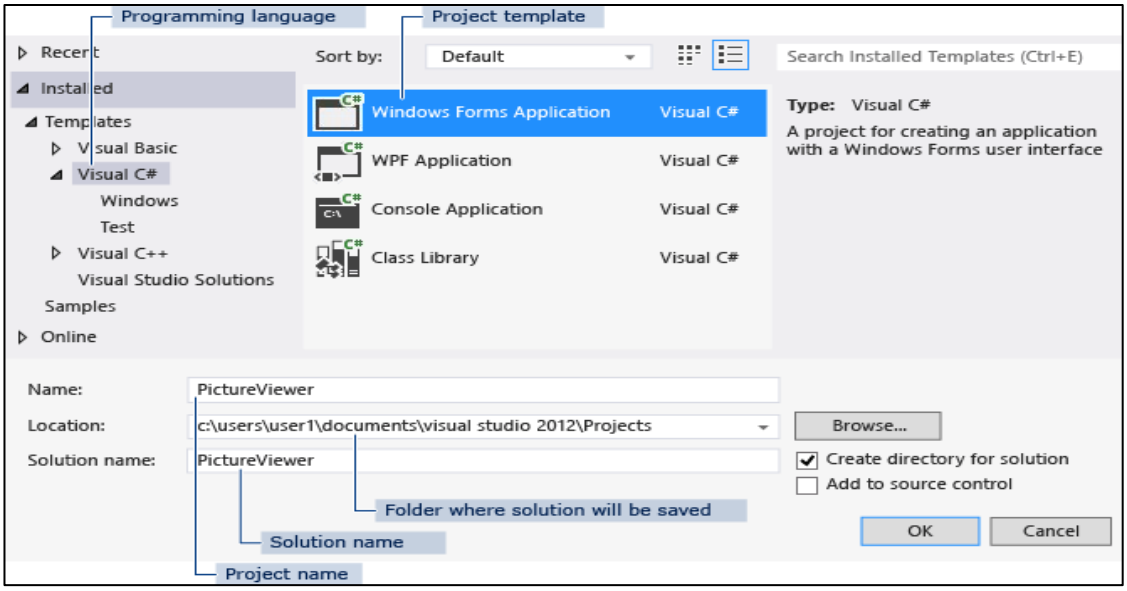
There are different ways of interacting between software and user which have evolved over the years. In computer science and human-computer interaction, the user interface of software refers to the most important types of it such as command line, graphical user interface (GUI), textual and form based. As we want to gather data from a user through a small questionnaire in order to make our software more users friendly it is better to

implement it in the form based type. A form-based interface uses text-boxes, drop-down menus, text areas, check boxes, radio boxes and buttons to create an electronic form which a user completes in order to enter data into a system. Visual C# has a suitable feature which can help us designing our questionnaire in a form based that called windows form application. This is one of two technologies that we normally use in Visual C# in order to build a suitable Windows-based application which can easily run on the .NET Framework. It gives us the full access to all the windows objects which called controls. These controls have been created by the .NET Framework before. The best applications have used these controls to create such a perfect and simple user interface.

There are two important and useful objects used in a Windows Forms application. First is forms and second one is controls. A form is the popular object which can easily fit into an application. It is a rectangular design and normally will use to display some information of application.

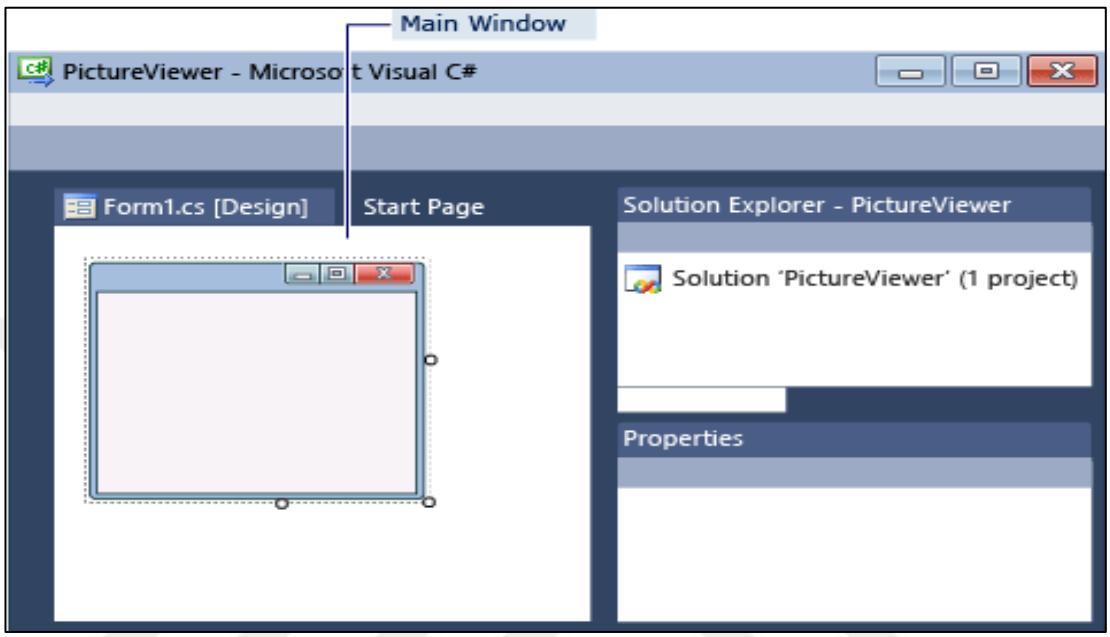
With brief describing about windows form application we will start to create the one for our questionnaire. To create windows form application as we have shown in the figure&& on the menu icon, we should select File**,** New Project and the first box to take our information is look like this.

Figure 3.9: Visual C# first page setting



After pressing OK, visual Studio automatically will build a solution file for our new program. A solution is like a folder to keep all the projects and files created by our program. The following figure shows the first thing we can see in the Visual Studio.

Figure 3.10: Form page in C#

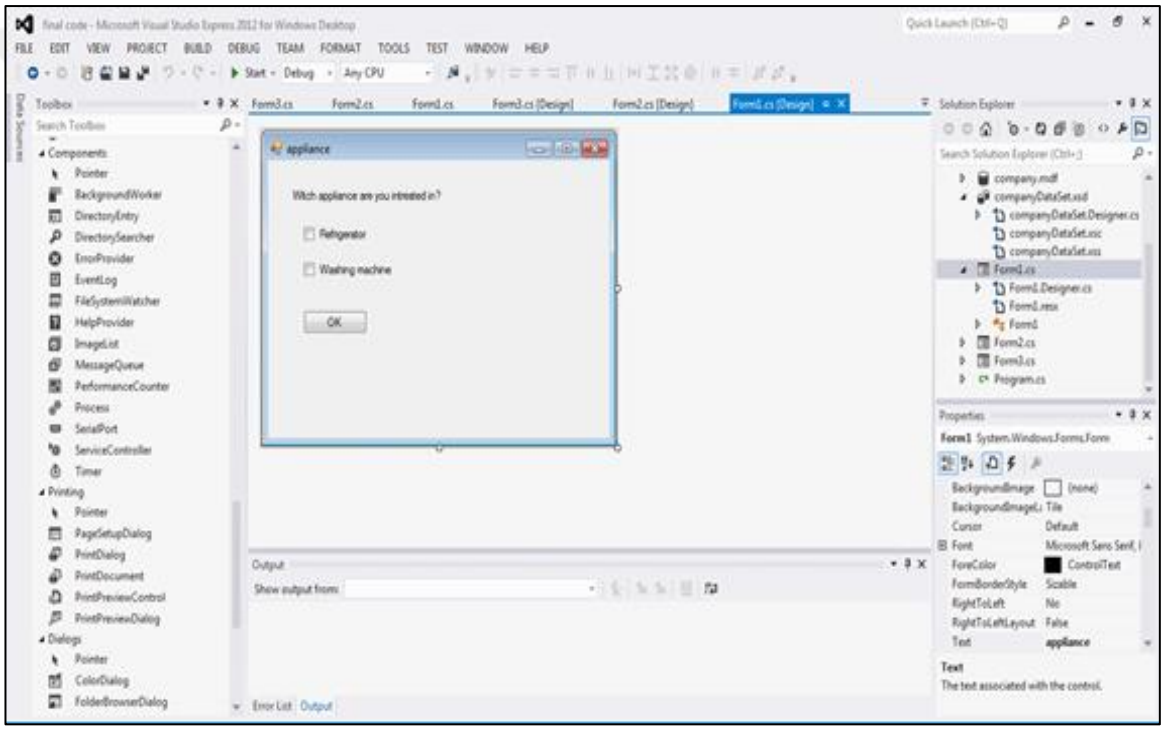


The interface includes three parts. First is main window that we can see all the objects in it, second is Solution Explorer and finally the Properties window which contains all the controls. The main window is going to be our small questionnaire. When we created a new solution, we actually built a program that runs. It doesn't do much yet. It just displays an empty window that shows Form1 in the title bar. But it does run, as we're about to find out. Windows Forms Designer will help us to change the way our form looks. It allows us to add controls like buttons, text boxes, menus, check boxes, radio buttons, etc. into a specific form and with managing them we can easily write code for special objectives.

As we mentioned before the aim of our questionnaire is to collect data from user and due to that we prepared different questions for different appliance types. Therefore to make our work more organized we have divided our questionnaire based on different types of appliance and displayed them in different windows. For example for washing machine we have different questions than refrigerator to ask from user so we presented

washing machine's questions in one window and also same thing for refrigerator. Also there is one window which will help user to choose his/her interested appliance in the first appearance of the software. Therefore as we wanted to implement our project only for 2 appliances in this study we have designed three windows using Windows Forms Designer to make more user friendly questionnaire. As you can see in figure $$ the first window will just ask user "which appliances you are interested in?" and we can easily choose one appliance and press ok to direct us to the desired next window.

Figure 3.11: First form of application in C#



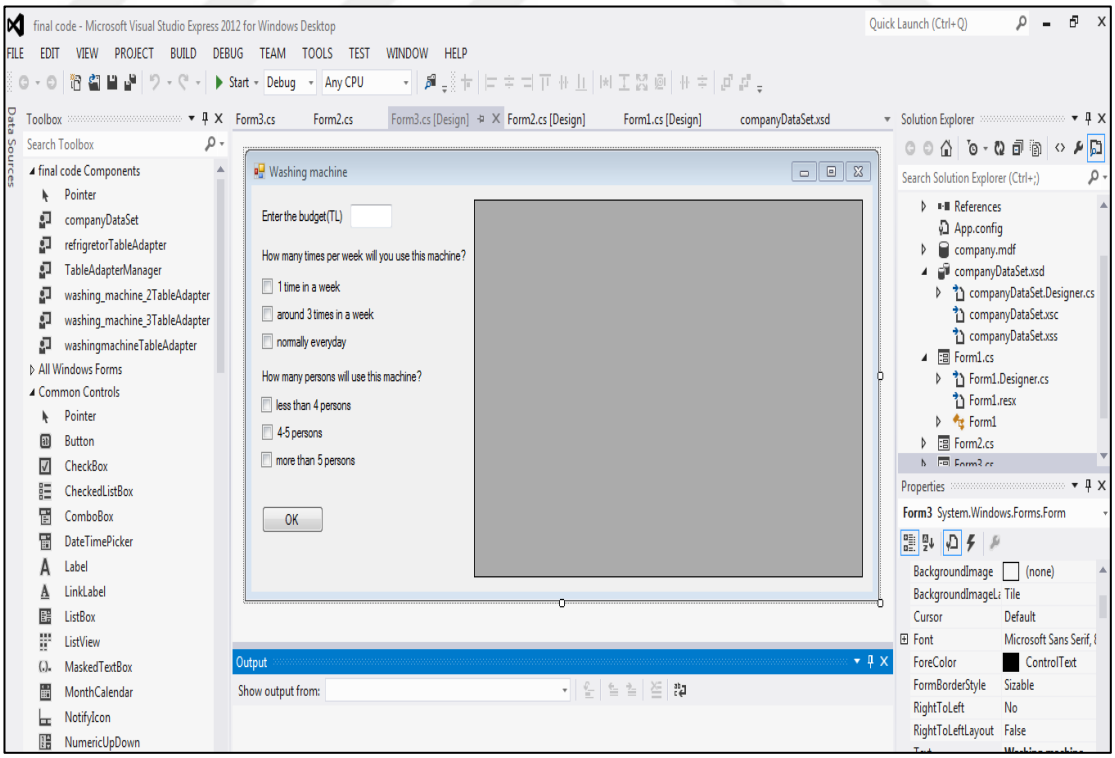
As you can see we filled our interface with some check boxes, button, labels and massages to make it user friendly for user to answer our question easily. Also notice the Solution Explorer on the right side of our screen. With Solution Explorer we can manage our items and tasks in a solution. Each form has .cs file which contain the main code of that form. Visual C# files use the .cs file name extension, which is short for "C sharp". This is the file that after designing the form we can write our algorithm's code based on the purpose we are following to get desired form.

For the first form the only aim that we are looking for is connecting to the correct page (form) according to the user's answer. Therefore we have written the suitable code for button item to connect user to the desired form. After this step we should design the washing machine and refrigerator forms separately.

As we have explained before because of different characteristics that each appliance types has therefore our questions based on each types will be different and in order to design our questionnaire precise it is better to divide it and implement each parts of it which is related to the specific appliances separately through different form.

For example for washing machine the proper question that we are looking to ask user are about number of time that user want to use device during the week and number of people who want to use it and also the budget of user that want to spend for that device. And also as we want to make a user friendly interface we should not make a complicated form for user to answer the questions. Therefore we can make multiple choice questions to make user feel free to answer.

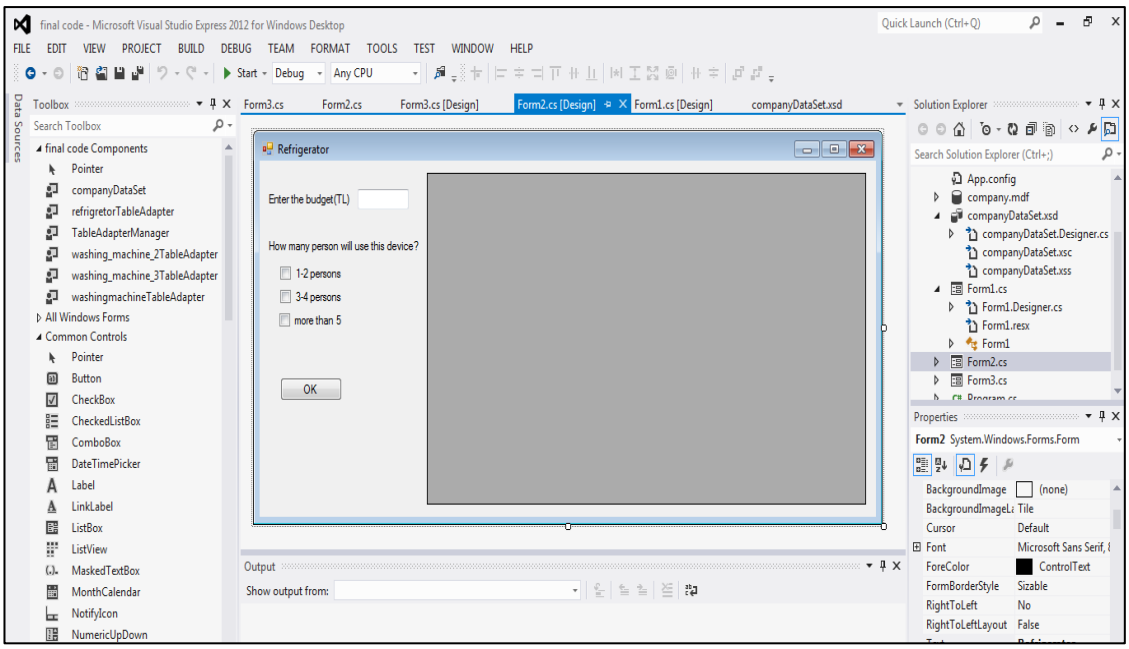
Figure 3.12: Washing machine form in C#



As you can see in the top of the form we are asking for user's budget and we have made a box to get the answer from user. After that we have asked "How many times per week will you use this machine?" and to answer this question we have 3 choices based on what we have explained before. And second one is about number of people who want to use device. We have designed this interface with some check boxes, button, massages and labels. And in the right part of the form as you can see there is a gray window which is for displaying the result after pressing the OK button. This gray window is object of the DataGridView which displays data from SQL databases. DataGridView is a useful control in Windows Forms application. The DataGridView control is extremely flexible and useful object, and it offers useful properties to manage its performance. The DataGridView control provides an effective final appearance of cells and display them as we want and help us to show our records from database therefore it would be good idea to use this control to show the result.

And the last form is about refrigerator. As this device is working nonstop we don't need to ask some questions like how many time will you use this device? Therefore the only items that we are looking for is that how many person want to use it and the budget of user. Here is the refrigerator's form.

Figure 3.13: Refrigerator form in C#



With designing all forms of questionnaire we will finish designing required instruments of this study and we can start to implement our main algorithm.

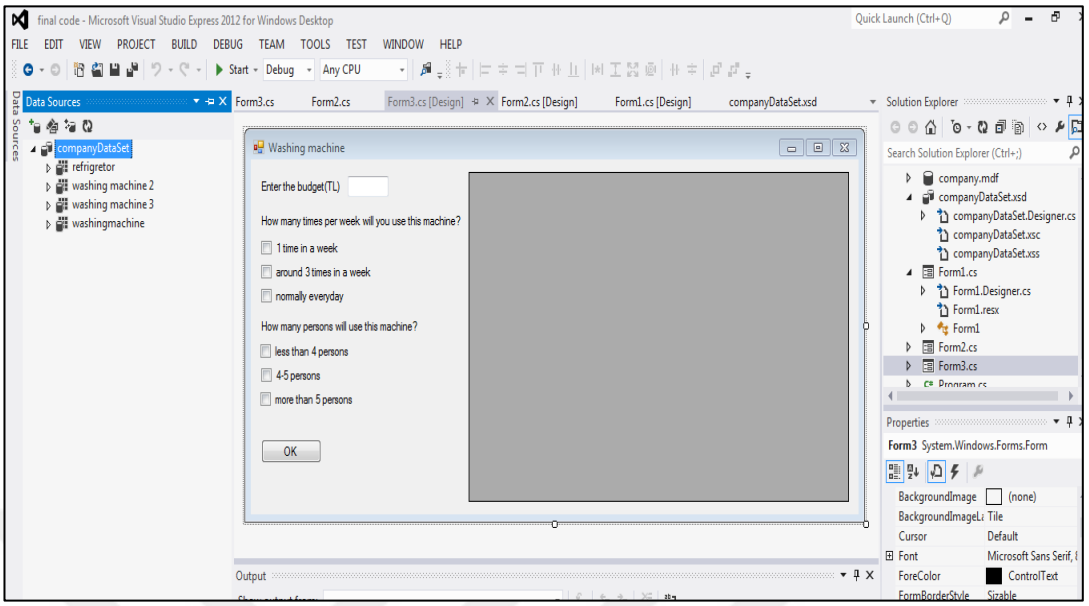
3.5 ALGORITHM

This section is about implementing mathematical algorithm written in Visual C#. In our software the algorithm will start to run after pressing OK button in that form and will use user's information which gathered before in the questionnaire forms. In this study we have designed our software to implement algorithm for each forms separately and almost same structure based on some elements such as budget, capacity, appliances price and energy cost. The main aim of the algorithm used in this study is to create a list of most efficient and suitable appliances based on the user's life style.

In this algorithm we will combine both user and appliance's information to get our desired result. So this is the time to transfer the appliance's records from our databases into the software in order to utilize by algorithm. This can be done through making connection between SQL Management Studio's databases with Visual C#.

In order to connect the algorithm of our software to the data which we have been stored in a SQL Server database we should use the property of .NET Framework Data Provider, and then we will copy all data in a proper data table that defined before in a main code section. So to be able to do this, we should make an instance for our Server object. The SqlConnection Object will make a proper communication between the SQL Server Database and our new C# application. The instance of SqlConnection crosses the value completely. After successfully set up the connection, SQL Commands will apply to control the records in the database. Once transiting the data the Connection between them should close. After making these steps we will have our database with tables connected to our software. Here in the left side of the figure 3.15 you can see our database icons with tables.

Figure 3.14: Transferred SQL database into the application in C#



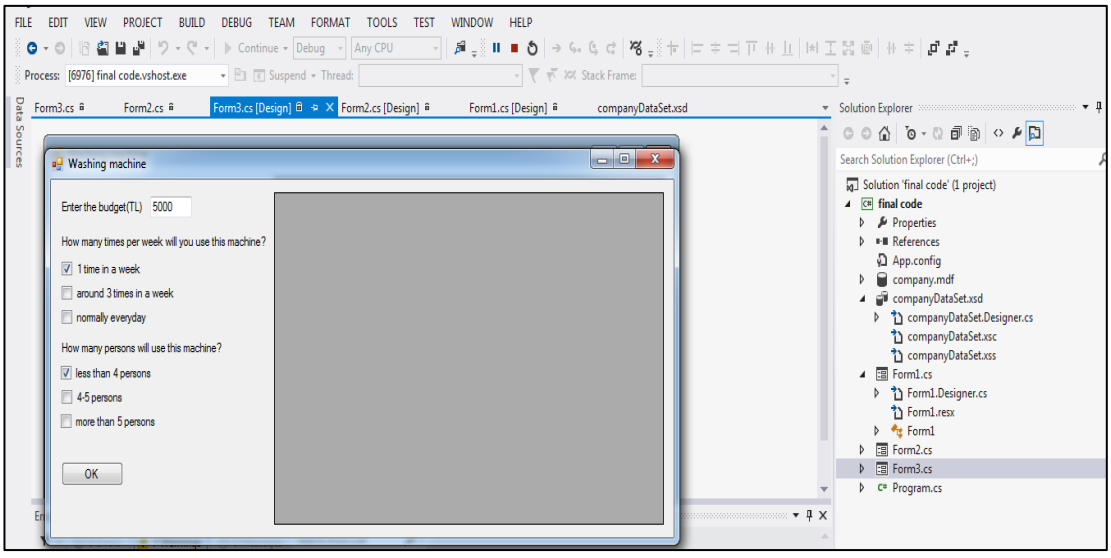
After making a connection to our data we have to sort our table table's data order by the cost of first year item by writing a proper query for them and run it in Visual C#. This sorting step will make a list of appliances that is ordered but this is not the correct result for different users with different demands and life style. Therefore with our software we need to sort again our data based on the budget of user and capacity that he/she needs. So the first task of the algorithm in order to give user a list of best fit for his/her life style is to find out devices with suitable capacity and at the same time less or equal price than user's budget. On the other hand, as the main goal of software is to promote a list of appliances based on less cost of first year to the user, therefore with respect to our primary conditions, second task of the algorithm is to sort proper devices ordered by cost of first year in order to create final list of most suitable appliances to offer user.

After connecting the software to our data the process of analyzing user's information obtained from software's form will start by the algorithm. This analyzing will start with checking the checkboxes that we have designed before for answering the questions. The algorithm in the washing machine's form after converting the budget value into the integer will make a copy from it to use it in the following parts. After that our algorithm will start to check each checkboxes to find out which one of them has chosen by user.

The first three checkboxes represent the number of time's options that user approximately may use devices and if you remember, when we were creating the tables for washing machine in the SQL Server, we decided to create three tables with same data except the cost of first year's column. These columns have filled for each table with the data that calculated based on the different number of time that user may want to use the device. Therefore, if a user chooses one of these checkboxes options, the algorithm directly will connect to the proper table to use data.

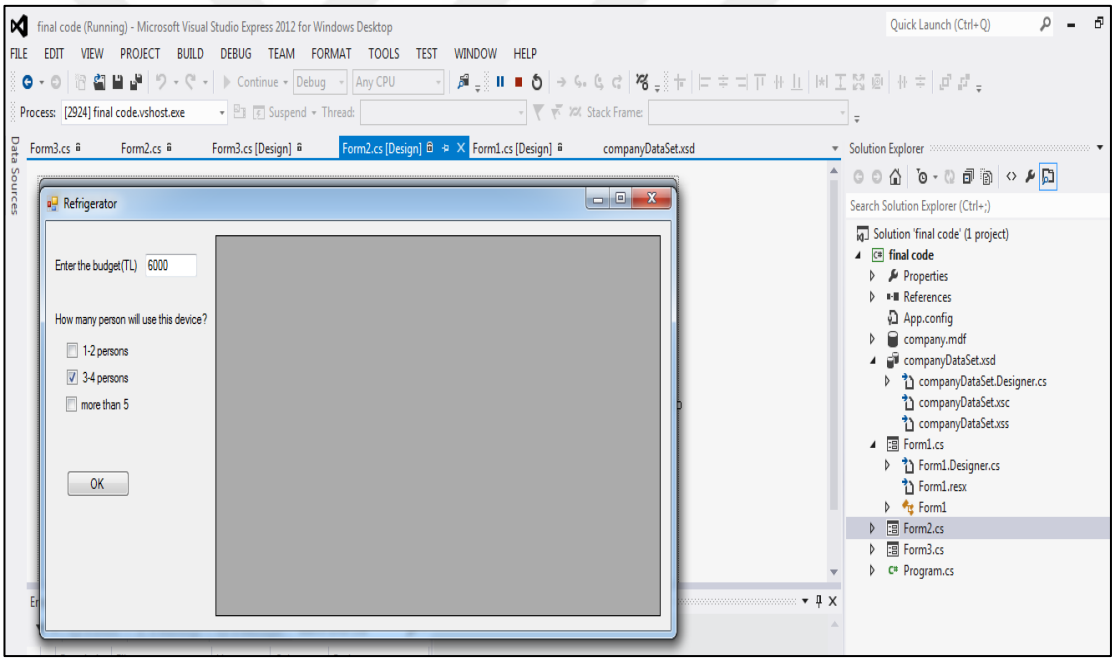
The second three checkboxes will refer to the capacity of devices. For example if a user chooses first option which is "less than 4 persons" the algorithm will offer him/her list of washing machines with 4 or maximum 5 capacity. It means after choosing one of these options the algorithm will start to finding the appliances with suitable capacity in the table to select and put in the list. So as a result the algorithm will work based on the conditions that user defined when he/she gave information to the software. As an example if a user chooses a washing machine and after entering budget to the form chooses "1 time in a week" for first question and "less than 4 persons" for second question, the algorithm will start to connect to the first table of washing machine and will find out washing machines with 4 or 5 capacity and less price than user's budget. After that it will start to sort them to find out the desired results based on the cost of first year and finally will display the list to the user.

Figure 3.15: Showing how to fill washing machine's form



The algorithm of refrigerator will work a bit different than washing machine. As we mentioned before the difference between refrigerator and washing machine's form is that in refrigerator form we don't need to ask "how many time will you use this device?". Therefore just capacity and budget are enough for software to find out most suitable refrigerators for user. As we have only one table for refrigerator's data, after user chooses one of the options related to the number of people who want to use this device, algorithm will connect to the refrigerator's table and will search for devices with suitable capacity for user and less or equal price than budget. After that it will sort them based on the cost of first year of each device and display the final list to the user.

Figure 3.16: Showing how to fill refrigerator's form



4. FINDINGS

As we mentioned before fast growing population is causing increase in creating and usage of home appliances by people and because of that we are facing with the one of the most challenging problem in today's world which is increasing energy consumption especially in residential sector. Almost all the researchers are trying to find out some solutions which can reduce this consumption optimally. Almost all provided models have a common property which is increasing energy efficiency in buildings that for all solutions of reducing energy is the most important aim. But what is energy efficiency for an appliance and how we can know whether a specific appliance is efficient for us or not and furthermore how we can find out the most energy efficient appliances between huge different models for our home? These questions led us to think about solutions in a different point of view and creating a model in order to help consumers figure out which appliances has most benefits for them.

In the previews chapter we have explained that the main objective of this study is to save both energy and money in residential buildings through choosing the most efficient energy home appliances and in order to achieve this goal easily we have designed and developed the software which will manage data and apply the optimization algorithm to the collected data that obtained from user information and also the prepared suitable database for this study. Since this software have designed for the consumer to find out their suitable appliance, so in order to see if the approach of this software can be useful for them or not we should test the software to get result out of it and analysis the data. But to analyze and discuss the result correctly in order to conclude precisely on the software performance whether that it can optimally help consumer to reduce their energy consumption or not, we should review the consumer's behavior or attitude (approach) toward buying the new appliance and also market reaction to consumer's attitudes. With estimating their attitude in this approach we can compare result of our software with that estimation easily and analyze data correctly.

Therefore this chapter contains two sections which have prepared to firstly discuss the consumer attitudes and later on show the result of the software. In the first section which is consumer attitude section we have reviewed the consumer approach toward

buying appliance and in the second section which is software's output section we have presented all the results of software's test.

4.1 CONSUMER'S ATTITUDE

Consumers play the most important role in the markets and all the business plans and industrial investments are based on the tastes, priority, habits and attitude of them. In another words, we can say all the market's efforts are being made to obtain maximum satisfaction of consumers. Therefore, researching about consumer's attitude toward buying appliance is the key of success in today's marketing.

Most of the consumers make their purchase decision for a product in order to satisfy their demands. There are so many factors which are involved in a purchasing procedure for a product. Some of the most important of these factors are economical situations, social and physical forces. Because of effect of these factors some of the consumer's purchase decision may not fulfill sustainability requirements for today's world which is energy efficiency consumptions. Since our objective is increasing energy efficiency by appliances, we can divide consumers based on those factors in 2 groups. First group contains consumers who financial conditions directly affect their choices for buying appliances. For example a consumer with a limit or even not enough budgets may not pay attention about if the appliance that he or she wants to buy is energy efficient or not. And because of those financial problems they are only looking for the most inexpensive appliances. On the other hand, there are some consumers with good financial situation who mostly are looking for luxury home appliances with their own desire of design, size or color instead of paying attention about price or energy efficiency.

Second group contains consumers who even despite of having some financial limits but still are looking for those appliances which are better and suitable for them with respect to the price. These consumers want to know which specific appliance has less or suitable price compare to other similar models and at the same time also use less energy. In order to find out which appliance is better for them normally they go to the different electronic shops and ask so many persons or may even look on the different online shopping websites due to easy access to the internet for almost everyone. The second groups of consumers who are looking to find suitable appliances based on price and energy consumption is the target of this study.

As we have mentioned before, with developing technologies in producing appliances and due to the need of reducing energy consumption especially in residential sectors most of the appliances manufacturer companies are producing devices which are more efficient than past. In order to promote energy efficiency technologies and encourage manufacturers to produce more energy efficient products and eventually save more energy, energy label program have been initialed to approve range of efficacy of different appliances. This labeling system can help and aware consumers for buying efficient products. In this labeling system the efficiency of the appliances is rated in order of energy efficiency classes which are from A to G.

On the other hand, this labeling system made a competition between companies to produce more devices with A class energy label. This label also can be a good property to advertise those appliances with A or B energy class. Therefore almost all the companies recently are producing appliances with A or B energy class.

Electronic shops, online shopping websites and all the shopping centers are guiding consumers to compare the different models of appliances based on the price and energy label of them in order to help consumers to choose suitable appliances. It means mostly they are offering the different models of appliances based on price and energy label to help consumers being energy efficient. We can say this is the approach and suggestion of the today's market for consumers to help them buy the most suitable appliances. We have simulated this approach with the SQL Management Studio.

After describing the consumer's attitude and market approach toward buying the home appliances we can test our software to see the result. In the next section we have presented the result.

4.2 SOFTWARE'S OUTPUT

As we mentioned in methodology chapter in order to use our algorithm which will work based on the database's data and user's information easily, we have developed user interface software which contains a small questionnaire that collects user's data and also has a perfect property that can connect to our database. Therefore to see a result from this software we should consider a user who wants to buy a washing machine and refrigerator and then answer questions as an example. We should remind again that in

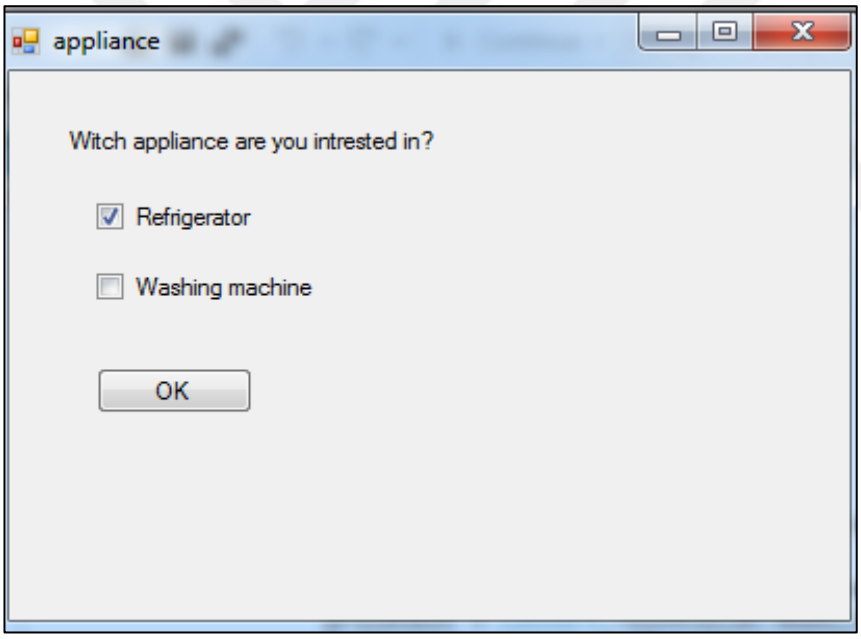
this study we have prepared the small database which contains appliance's data of 2 brands.

In order to examine if the approach of this study and result of Visual C# software can fulfill our objective, we have presented the data of SQL Management Studio which we already used to develop our database to compare with final result of this study. First we present the result of Visual C# for each appliance.

4.2.1 Visual C#

So after running the software we will face with a first form which is like a menu to choose our proper device.

Figure 4.1: First form of C# application after running

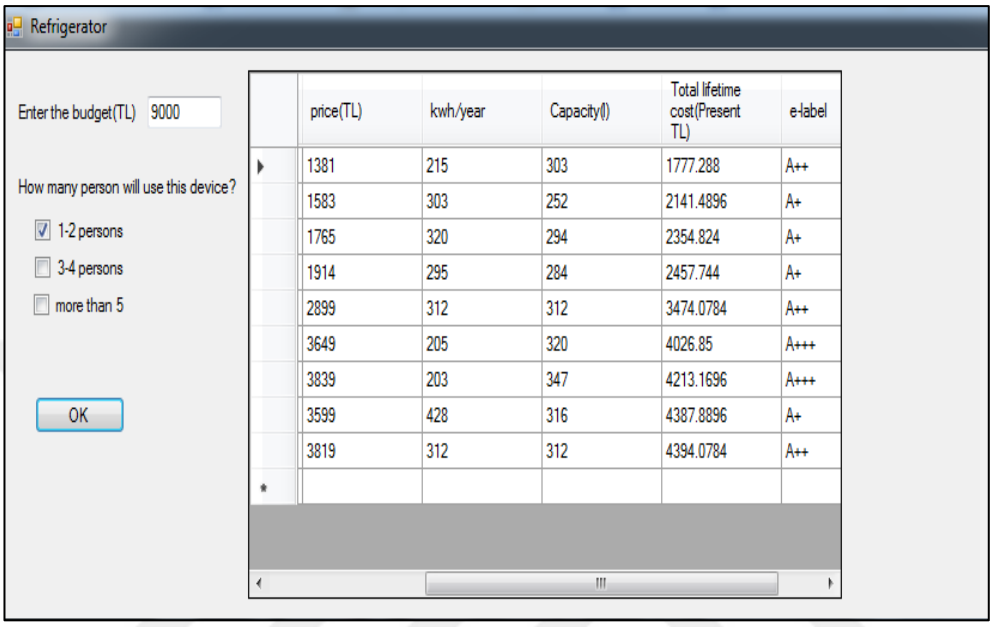


4.2.1.1 Refrigerator

As it has shown, first we have chosen the refrigerator to find out the most suitable model. In the next page the refrigerator's questions form will appear which needs to complete by user. The questions are user's budget and number of people who want to use this device. As an example, we have filled the budget price with 9000 Turkish Lira

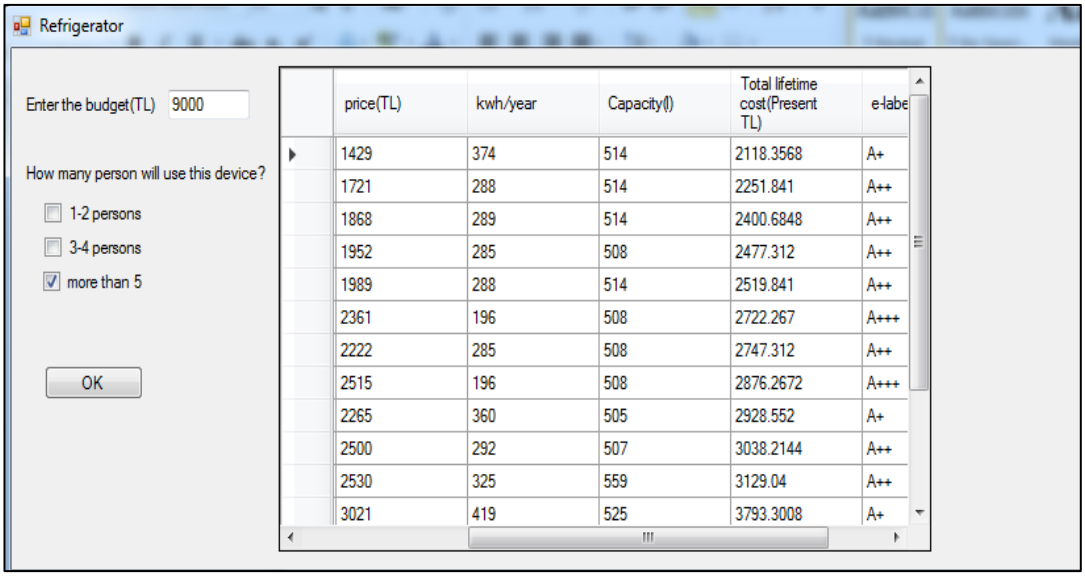
and also considered a family just with 2 persons so we have chosen first option which is for 1-2 persons. Now after filling the form we can press OK button to see the result.

Figure 4.2: First result of C# application for refrigerators



As another example we have chosen third option which is more than 5 persons and here we have shown the result.

Figure 4.3: Second result of C# application for refrigerators



4.2.1.2 Washing machine

Next appliance is washing machine.in order to see result of this appliance we should run the software again and in the menu form choose washing machine. After pressing Ok button the washing machine's form will appear and we have to fill the questions.

First question is asking the user's budget. As a first example we wrote 8000 Turkish Lira. As it has shown in the figure 4.4 for the second question which asks "how many times per week will you use this machine?" we have chosen second option which is "around 3 times a week" and for last question which asks "how many persons will use this machine?" we have chosen third option which is "more than 5 persons". And in another figures we have shown the results of the software for same budget and different answers.

Figure 4.4: First result of C# application for washing machine

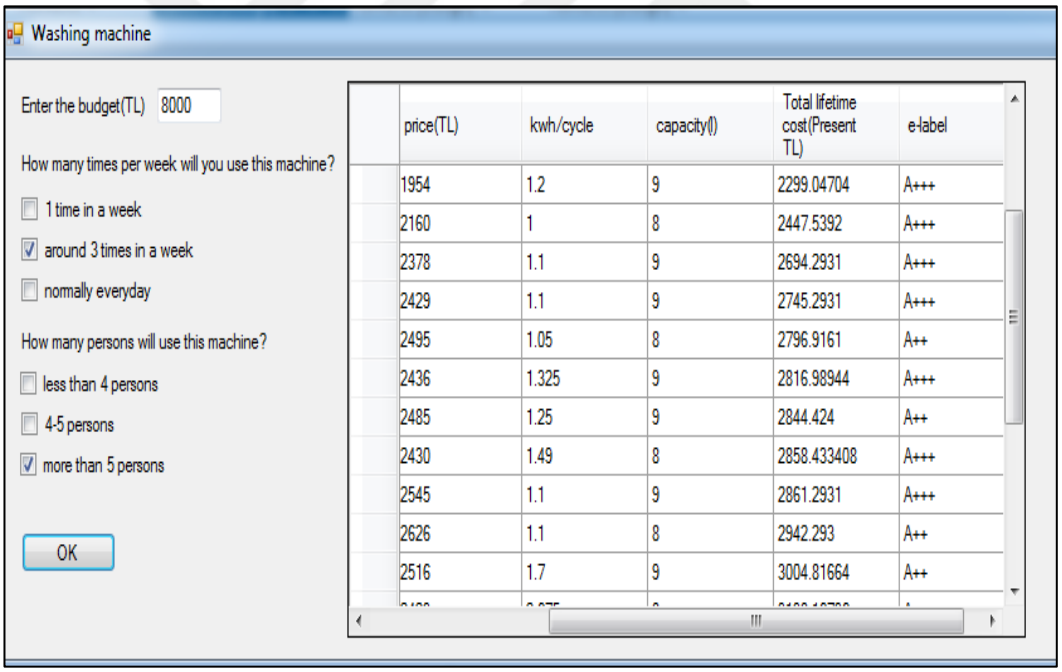


Figure 4.5: Second result of C# application for washing machine

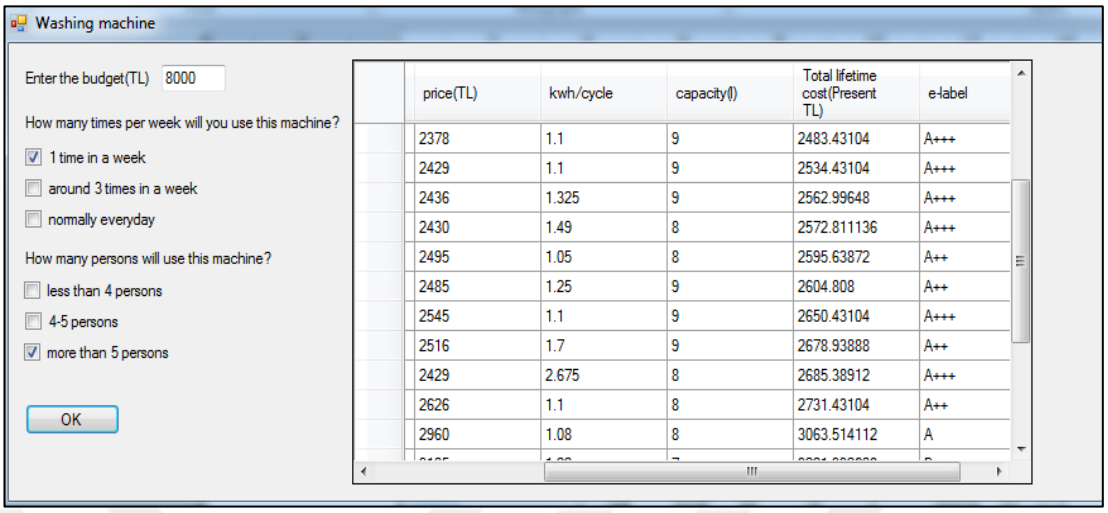
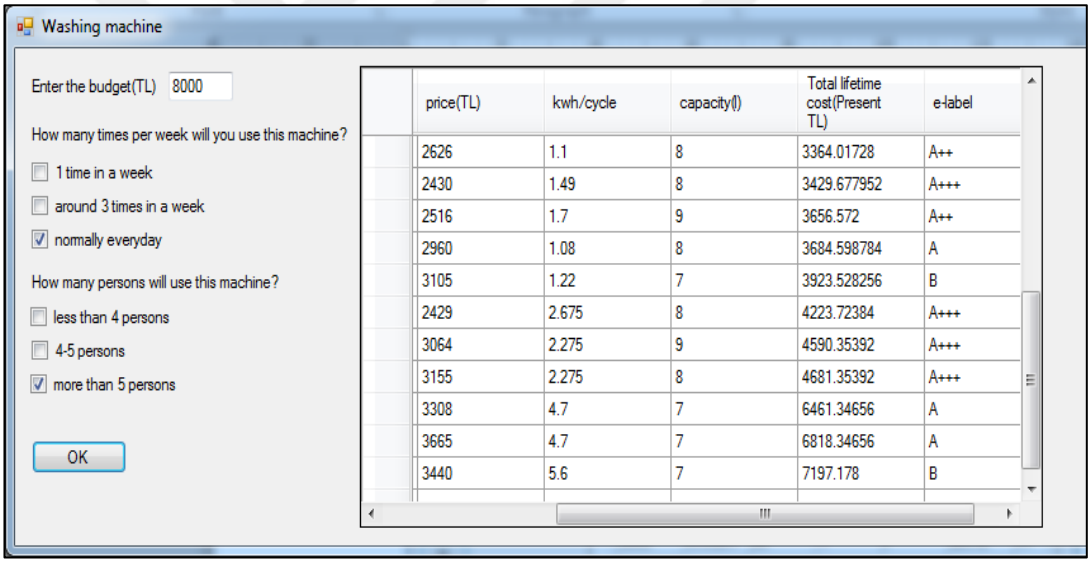


Figure 4.6: Third result of C# application for washing machine



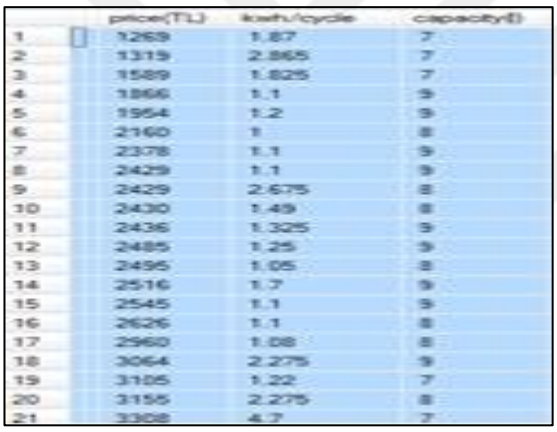
4.2.2 SQL Management Studio

As we have explained before for the types of consumers who take their purchase decisions toward buying a household appliances based on both energy consumption and price, there are lots of sources like electronic shopping centers or online shopping websites that they can search their desire appliances. Seller's approach in most of the electronic shopping centers toward guiding consumers is that they normally offer consumers some appliances which have suitable capacity for consumer's family and

then refer them to the energy label of appliances in order to compare those appliances based on both energy label and price. This approach is same for online shopping websites. We can estimate this approach of sellers by using SQL Management Studio. As we have mentioned before we created a database for our model which contains the appliance's data. With sorting the data table based on price and capacity we can simulate the online shopping websites and shopping center's approach toward offering different appliances to the consumers. So the following tables will show a part of SQL result for washing machine and refrigerator. We have assumed a consumer with more than 5 person members is looking for a washing machine and refrigerator.

4.2.2.1 Washing machine

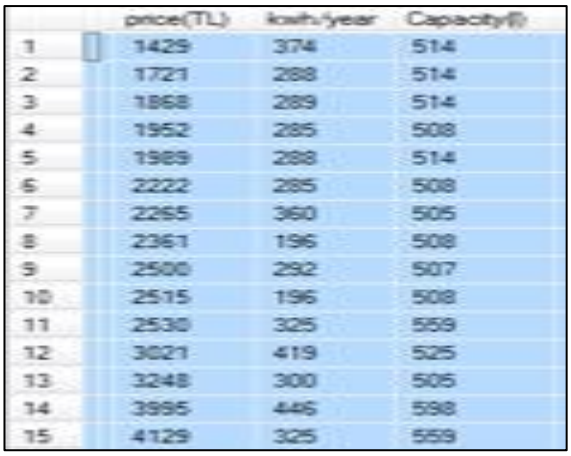
Figure 4.7: First result of SQL Management Studio for washing machine



	price(TL)	kwh/cycle	capacity(l)
1	1269	1.87	7
2	1319	2.865	7
3	1589	1.825	7
4	1866	1.1	9
5	1954	1.2	9
6	2160	1	8
7	2378	1.1	9
8	2429	1.1	9
9	2429	2.675	8
10	2430	1.49	8
11	2436	1.325	9
12	2485	1.25	9
13	2495	1.05	8
14	2516	1.7	9
15	2545	1.1	9
16	2626	1.1	8
17	2960	1.08	8
18	3064	2.275	9
19	3105	1.22	7
20	3155	2.275	8
21	3308	4.7	7

4.2.2.2 Refrigerator

Figure 4.8: Result of SQL Management Studio for refrigerators



	price(TL)	kwh/year	Capacity(l)
1	1429	374	514
2	1721	288	514
3	1868	289	514
4	1952	285	508
5	1989	288	514
6	2222	285	508
7	2255	360	505
8	2361	196	508
9	2500	292	507
10	2515	196	508
11	2530	325	559
12	3021	419	525
13	3248	300	505
14	3995	446	598
15	4129	325	559

5. Discussion and conclusion

In the previews chapter we have shown the result of 2 software which one of them represent the approach of this study and another on represent the approach of sellers and online shopping websites toward guiding customers to choose a best home appliances. In this chapter we have compared and discussed the results and finally concluded that if the approach of this study and the software that we have developed can fulfill the objective of this study which is optimizing energy consumption in residential sectors by efficient appliances.

Therefore this chapter contains 2 major sections. In discussion section we have compared and analyzed result of 2 software for each appliance. In the second section which is conclusion, we have restated our study and discussed what we have done in this thesis as a conclusion.

5.1 DISCUSSION

Before discussing the result we should clarify some concepts. As we have explained in the previews chapter, there are two groups of consumers who want to buy household appliance. The second groups of consumers who want to search to find suitable appliances based on price and energy consumption is the target of this study. As we have mentioned before, many manufacturers have forced to produce more efficient productions in order to increase energy efficiency by appliances. This can prove by energy labels. As we can see in today's market, most of the appliances have "A" or more energy class labels. But obviously energy label despite of being a good factor for comparing energy efficacy of appliances is not a sufficient reason to choose the most suitable appliances for consumers. It means having high energy label for the efficient appliance is a must and primary condition but it is not an enough factor for different consumers to choose the suitable efficient appliance only base on this in order to reduce the energy consumption in home. That is why researchers are trying to create and provide proper models with considering different factors for consumers to reduce energy consumption in home.

On the other hands, since most of the consumers don't have enough time, knowledge or interest about energy concepts like energy efficiency calculations, therefore they mostly take their purchasing decisions based on price of appliances and not watts and kilowatts. The important issue that most of the consumers don't know is that buying appliance based on initial price or shortly the cheapest products will not be the last and reliable and may cause consumers spend more money on bills, repairing cost and etc. in the future. That is why giving useful and at the same time simple information about different appliances to the consumers in order to make a clear vision about which specific appliance is more energy efficient and why it is better than another similar model, can help them to choose an energy efficient appliances. This clarifying the concepts and giving useful and simple information based on energy efficiency that helps consumers to take their purchase decisions more beneficially toward buying household appliances is the main purpose of this study and the software that we have developed. The most important concept that in this study we have used in order to compare different appliances is total lifetime cost of appliances in Turkish Lira currency. In the next section we have discuss it more.

5.1.1 Total lifetime cost (TL)

Total lifetime cost of an appliance means all the costs which are related to an appliance such as running costs, repairing costs and insurances or etc. plus the purchase price of it. This concept normally used for evaluation of appliances to analyze their performances over times and also it is a good option for decision making for consumers to choose a useful and desire appliance. In this study we estimate this cost based on initial cost and running cost over the lifetime. Running cost is the total cost of operating appliance in a specific time and it acquire directly from energy consumption of appliance. Therefore since energy efficient appliances toward inefficient appliance have smaller energy consumption, the running cost of them will be smaller than inefficient appliances. That is why choosing a cheaper appliances are not always a good solution for reducing energy consumption of appliances. And on the other hand, some of the expensive appliances are more efficient and will use less energy and therefore running cost of them is normally lower.

Although, running cost of energy efficient appliances are smaller than other models, but since most of them are more expensive than inefficient appliances, therefore adding these 2 numbers for all appliances and then comparing them based on this result can optimally show us the most energy efficient and at the same time reasonable price appliances.

Our software uses this approach in order to compare different appliance's performance. In order to clarify the result better, we have explained the result of each types of appliances separately. First we have started with refrigerator.

5.1.2 Refrigerator

Here to make a better comparison, we have showed some of the results of both software again. For both of them we have assumed as an example that a consumer with 5 person family members and 9000 Turkish Lira as a budget is looking for a suitable refrigerator.

Figure 5.1: Result of C# application for refrigerators

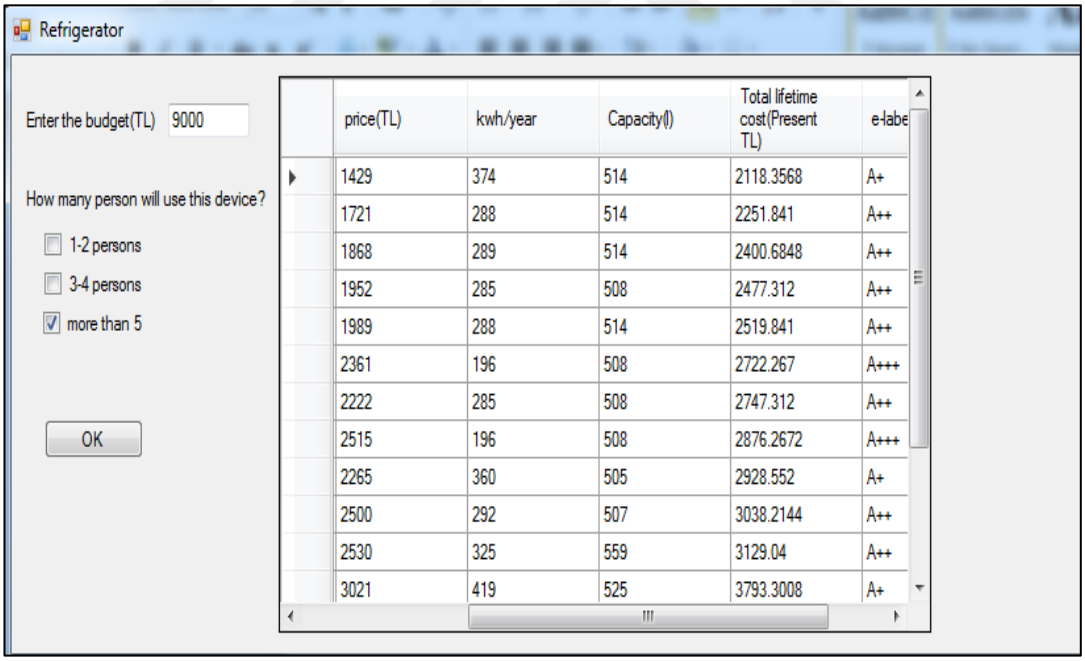
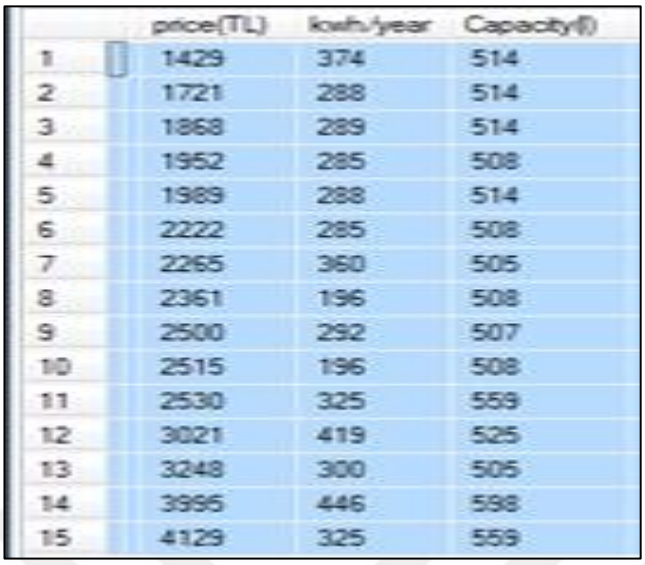


Figure 5.2: Result of SQL Management Studio for refrigerators



	price(TL)	kwh/year	Capacity(l)
1	1429	374	514
2	1721	288	514
3	1868	289	514
4	1952	285	508
5	1989	288	514
6	2222	285	508
7	2265	360	505
8	2361	196	508
9	2500	292	507
10	2515	196	508
11	2530	325	559
12	3021	419	525
13	3248	300	505
14	3995	446	598
15	4129	325	559

As we can see from result of SQL Management Studio, appliances have listed based on prices with respect to the capacity and the result of Visual C# has sorted based on the total lifetime cost in Turkish Lira with respect to the capacity. And for both lists, the appliances have ranked from the best efficient in the top to the less efficient in the down. To understand the difference between results better, we can choose 2 appliances as an example for comparing.

For example, from the C# list we can understand that the refrigerator with 2361(TL) price is more efficient than the refrigerator with 2222 (TL) price because of less total lifetime cost of it. But it has shown in the SQL list oppositely. As we can see from this list the refrigerator with 2222 (TL) price has listed in the higher position than the refrigerator with 2361 (TL) price because the less price of it.

This difference is exactly the main goal of this study. To show that since some appliances are more expensive than other models but with less energy consumption, it will deserve to buy the expensive ones because even with assuming the purchase price in the total cost of those appliances that we should pay over lifetime of them as a total lifetime cost, still it will be cheaper than the total lifetime cost of those cheap appliances with high energy consumption.

5.1.3 Washing machine

The issue that we have concluded from refrigerator results is exactly same for washing machine. Here again we have shown the results of both SQL and C#.

Figure 5.3: Result of C# application for washing machine

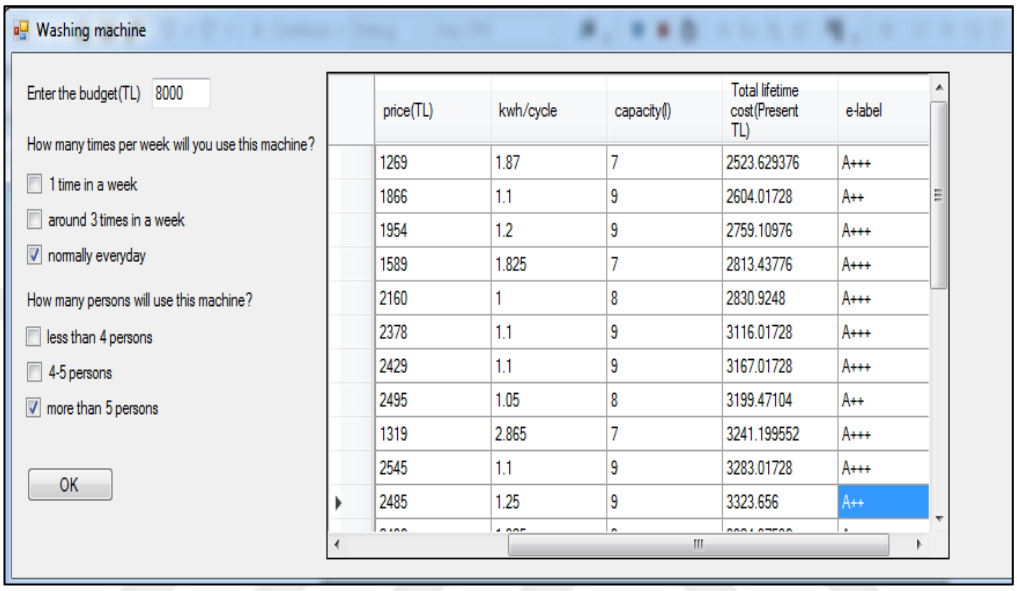
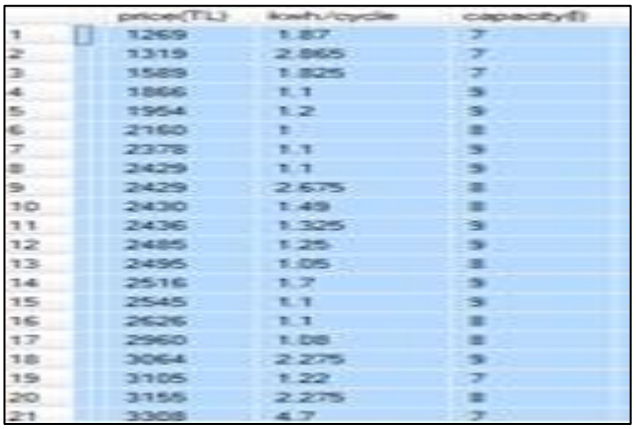


Figure 5.4: Result of SQL Management Studio for washing machine



In the C# we have assumed that a consumer that uses the washing machine almost 3 times in a week and has a family member of 5 and also with 8000 (TL) budget is looking for buying washing machine. Again we can see some differences between the

results of SQL and C#. For example, from the C# list we can understand that the washing machine with 1954 (TL) price is more efficient than the washing machine with 1589 (TL) price because of less total lifetime cost of it. But it has shown in the SQL list different. As we can see from this list washing machine with 1589 (TL) price has listed in the higher position than the washing machine with 1954 (TL) price.

So again from the result we can understand that a model of washing machine with less energy consumption but expensive price compare to the price of another model of washing machine with almost same capacity but high energy consumption, will be financially better over a lifetime period of those appliances.

As a result of our software we can highlight another important property. But before that we have to show some result of our software for washing machine.

Figure 5.5: Result of C# application for washing machine when second option has chosen

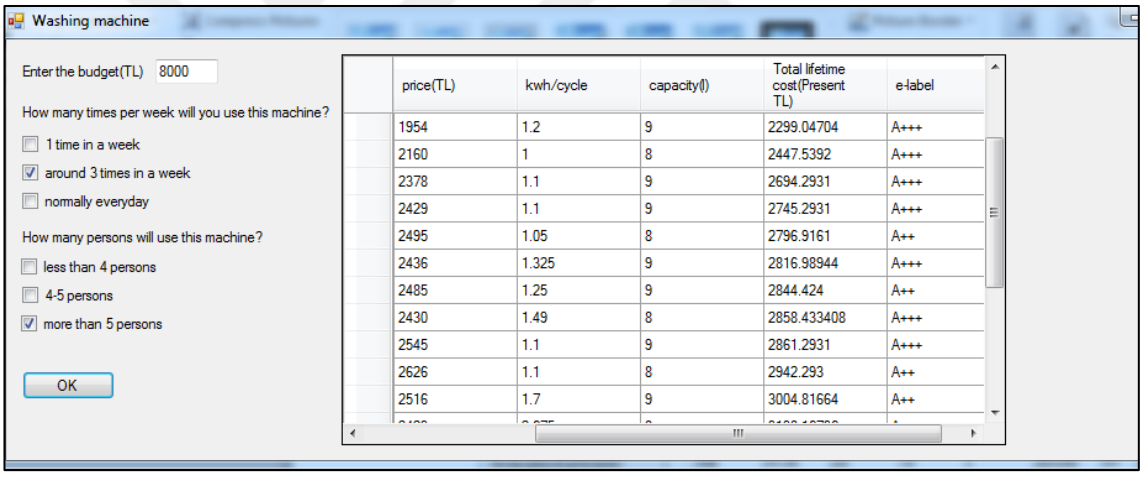


Figure 5.6: Result of C# application for washing machine when first option has chosen

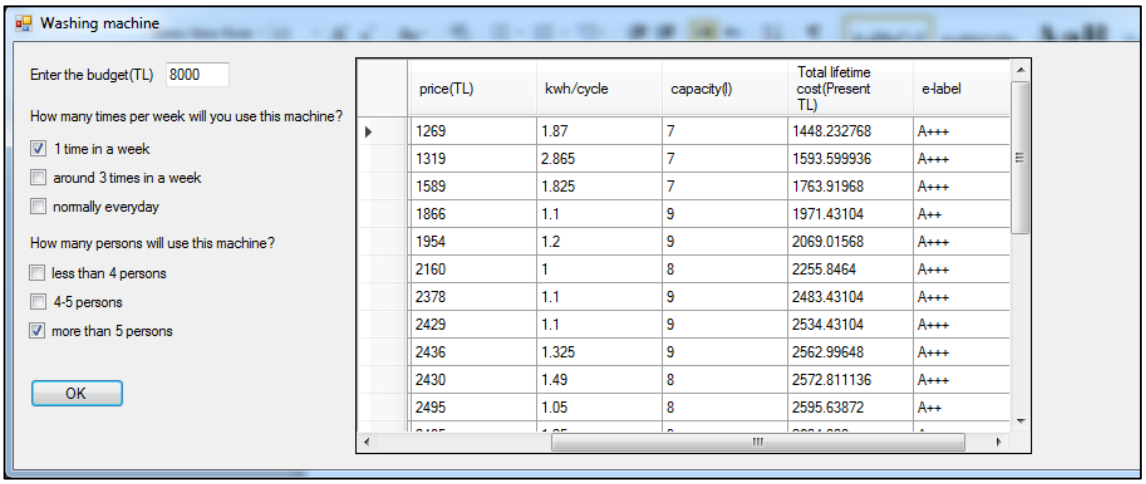
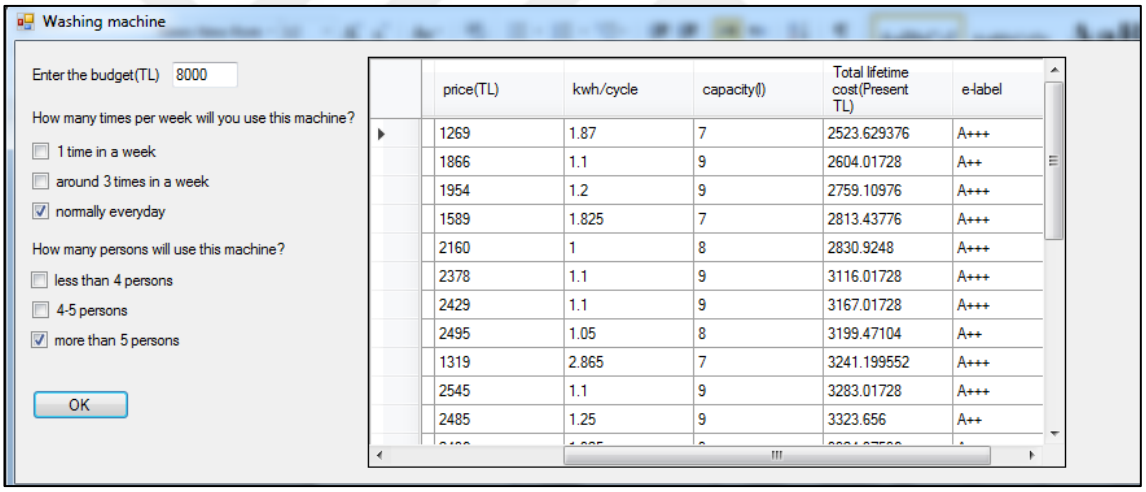


Figure 5.7: Result of C# application for washing machine when third option has chosen



These forms show the result of same budget and capacity but different approach in using washing machine. As we have explained before number of time that user may use washing machine is an option to estimate the energy cost of appliance over a year. With looking into the result we can understand that if a user use washing machine few times in a week with choosing the first option which is “1 time in a week” the software shows the result more look like it sorts appliances based on their prices. This result is logic and we can approve it.

The equation that we have used to calculate total lifetime cost will add initial price to the multiplication result of energy consumption cost and number of times that user may

use appliance, and since the number of time is 1, as a result an efficient appliance with high price and less energy consumption will have a lower position in the result list than a cheap appliance with high energy consumption.

With assuming the number of times that user use washing machine 3 we can see more disorder in that the result. This is because we have same initial price and energy consumption cost but we increased the N. With putting N 7 we can see the most disorder in the last figure. The reason refers to the multiplication result of energy consumption cost and N. Since again we have same initial price and energy consumption cost, multiplication of the small energy consumption with 7 will be smaller than high energy consumption with 7. And on the other hand, because we increased N so the result of this multiplication will have bigger portion of total lifetime cost. Therefore total lifetime cost will depend more to the multiplication result of the energy consumption cost and N. This impact affects the result in a way that efficient appliance will come more up in the list of result and inefficient appliances will go more down. That is why we can see the disorder in the result of third form more than first form.

These results have shown another important goal of our software. We wanted to show that if a consumer normally will not use an appliance in home due to his or her life style it may be a good idea to buy an appliance based on price of it and of course energy label and capacity. But if a consumer normally uses a specific appliance so much, it is better to take purchase decision based on the total lifetime cost and capacity.

5.2 CONCLUSION

While population growing fast and continually, developing buildings and increasing number of home appliances as a result of it will cause energy consumption become a significant challenge in today's world. Since we cannot control directly this increasing number of appliances, improve using energy in buildings by appliances would be one of the affective idea to save energy and money and also minimizing environmental impacts. Therefore energy efficiency in building by household appliances became the important aim for researchers to provide different models for consumers to reduce their energy consumption. Some of the most important approaches are like using smart

meters, energy management systems and also scheduling the appliances operations. Although these approaches have some advantages to reduce energy consumption in home, but since buying these devices are expensive, some of the consumers would not prefer to buy them in order to control their energy consumption. Therefore reducing energy consumption directly from household appliances can be affective approach for saving energy in home. In this approach we have to choose the most efficient appliances and also suitable for consumer's life style. Different brands and also models of appliances with high energy efficiency can make consumers confuse and also convince to buy between them a cheapest appliance. But cheapest appliances are not always the efficient appliances. In another word, since most of the consumers are not familiar with some concepts like energy efficiency for appliances and also because of busy life style may not pay attention about efficiency, therefore if one source guides them with useful and simple information about how to find efficient and suitable appliances, can affectively improve energy consumption by appliances in home. This issue has made us motivated to develop an idea through proper software which helps consumers to choose the energy efficient home appliances based of their life style.

In this study we have developed software that works based on the consumer's information and also appliance's details. SQL Management Studio is the first software that we have used to collect and store data of appliances and Visual C# is another software that we have implemented our main algorithm. In this study we have decided to test the software just for refrigerator and washing machine and also BOSCH, ARCELIK and SIMENS are 3 brands company that we have chosen to collect some technical data from these 2 types of appliances.

In Visual C# with using some questionnaires we collect user's information and based on their answers we connect to the proper table of our appliance's records and then the main algorithm can start to run to calculate these data and show the result to the user. On the other hand, we have simulated the online shopping websites or seller's approach toward guiding consumers to choose a suitable appliances using SQL Management Studio.

Since consumers mostly are not familiar with kilowatt and watt units, it will be easier for them to compare appliances based on cost of energy and appliances. In the Visual

C# the appliances have sorted based on total lifetime cost in Turkish Lira. The advantage of filtering appliances based on this option is that the appliances with less running cost due to the less energy consumption but expensive purchase prices will appear in the list of result in the better rank than the appliance with less purchase price but high running cost due to the high energy consumption. This approach is the main purpose of this study in order to suggest an efficient appliance to the consumer.

As it has shown in the result chapter, the results of both software have some similarity. We believe that this similarity happened just because we have collected small database for appliances for testing. In the reality there are hundreds of different appliances in the market that if we collect their information and implement the software on them, this similarity will be narrow down.

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