PROPOSAL FOR A SOFTWARE MODEL BASED ON THE CRITICAL ANALYSIS OF PACKAGES USED IN INTERIOR ARCHITECTURE

A THESIS
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MASTER OF FINE ARTS

By
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January, 2008

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Fine Arts.

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ABSTRACT

PROPOSAL FOR A SOFTWARE MODEL
BASED ON THE CRITICAL ANALYSIS OF PACKAGES
USED IN INTERIOR ARCHITECTURE

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Interior architectural education and practice employ various different general purpose software packages. Nonetheless, this study claims that as none of packages is developed specifically for interior architectural design process and purposes, both interior architecture education and market seek ways to fulfill their specific needs.

This study aims at proposing a model for domain specific software for interior architecture. Within this conception, initially, general purpose and domain specific CAAD software used in interior architecture are defined. Then, selected software are analyzed according to 'drawing', 'transformation', 'view', 'rendering' and 'other' features. Interior architectural domain specific requirements are obtained as a result of these analyses and comparisons. Consequently, questionnaires and interviews are performed with interior architectural students and professionals in order to determine user needs. The analysis of the user needs provide significant background information about software features and quality attributes of the proposed model.

Keywords: Interior Architecture, CAAD, General Purpose Software, Domain Specific Software, Software Features, Software Quality Attributes

ÖZET

İÇ MİMARLIKTA KULLANILAN YAZILIM PAKETLERİNİN KRİTİK ANALİZİ SONUCUNDA BİR MODEL ÖNERİSİ

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Ocak, 2008

İç mimarlık eğitiminde ve piyasasında çok fazla sayıda genel amaçlı bilgisayar yazılımı kullanılmaktadır. Ancak, bu çalışmada da belirtildiği gibi bu genel amaçlı yazılımların hiçbiri iç mimarlık tasarım süreci ve amacı çerçevesinde geliştirilmediğinden, eğitim ve piyasada iç mimarlığa özel ihtiyaçların giderilmesi için yeni yollar aranmaktadır.

Bu çalışmada iç mimarlık için özel amaçlı bir bilgisayar yazılımı modeli geliştirilmesi amaçlanmıştır. Bu bağlamda, öncelikle iç mimarlıkta kullanılan genel ve özel amaçlı bilgisayar destekli mimari tasarım yazılımları belirlenmiştir. Daha sonra, seçilen bilgisayar yazılımlarının 'çizim', 'dönüşüm', 'görünüş', 'kaplama' ve 'diğer' özellikleri doğrultusunda analizleri yapılmıştır. Yapılan analizler ve karşılaştırmalar doğrultusunda iç mimarlık alanına özel gereksinimler tespit edilmiştir. İzleyen bölümde ise kullanıcı gereksinimlerini belirlemek için iç mimarlık öğrencileri ve bu alanda çalışan uzmanlar ile anket ve görüşmeler yapılmıştır. Bu anket ve görüşmeler neticesinde oluşturulan analizler önerilen modelin yazılım özellikleri ve kalite özellikleri hakkında önemli bilgiler sunmaktadır.

Anahtar Kelimeler: İç Mimarlık, Bilgisayar Destekli Mimari Tasarım,
Genel Amaçlı Yazılım, Özel Amaçlı Yazılım,
Yazılım Özellikleri, Yazılım Kalite Özellikleri

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I dedicate this thesis to my husband and to my family.

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1. INTRODUCTION

The need of an interior space first emerged in prehistoric times to meet primary human needs of getting warm, sleeping and eating. Despite this fact, the profession of interior architecture has not been recognized for centuries. Until the twentieth century, architects, engineers, builders, joiners, plasterers, textile designers, fine artists and furniture designers had advised on the arrangement of the interiors rather than interior architects (Massey, 2001).

Interior architecture first appeared as the continuum of interior decoration. With the improving needs of society, interior decoration became a profession called interior design. Interior design can be defined as "a multi-faceted profession in which creative and technical solutions are applied within a structure to achieve a built interior environment" (NCIDQ, 2004). However, there is still a distinction between interior architecture and interior design. Interior architecture has strong links with architecture. Interior architecture is composed of design choices embedded within the building inside as well as out, and as such must be housed within the practice of architecture and professional architectural services (Hildebrant, 2004). Although the design processes of interior architecture and interior design share the same procedural sequence and a core discipline vocabulary; interior design, both as a discipline and in its product, is free of the weight of the interior architecture (Hildebrant, 2004).

Through the history, interior spaces were considered as an inseparable part of the entire structure and most of the time they were designed by architects. Also, architectural movements and styles of the time affected interior designers and design applications. In the twentieth century, influenced by architecture, interior architectural professionals presented two different approaches (Tate & Smith, 1986); those closely followed historical traditions of the past and those who explored innovation and invention. The second approach was carried by the works of Frank Lloyd Wright (1867-1959) who was considered to be the pioneer of modern interiors since he was the first to develop "interpenetration of interior and exterior space" (Tate & Smith, 1986, p. 265). Wright's unifying approach of interior and exterior is significant in interior architecture's emerging as a new specialized branch within architecture (Demirbaş, 2001).

The emergence of interior architecture as an independent discipline may seem recent when compared to the history of architecture, yet it had a strong impact. The communication and interaction between the two disciplines are dense and close. Interior architecture borrows a lot from architecture, such as its terminologies, theories and styles. Interior architecture also makes use of architectural software. In education and practice, interior architecture generally uses software comprising operations related to a large spectrum of architectural design activities.

1.1 Problem Statement

As interior architecture revealed as a new discipline depending on architecture, they are seen inseparable in many ways. Interior architects have been using the same tools with architects in design and practice, and recently with the emergence of technological tools they began using the same software packages. However, interior architecture is a distinct design field which differs in focusing on interior space's detailed design requirements related to color, texture, lighting, heating, acoustics (TMMOB, 2005) and owes its existence to these details. These details put forth a special characteristic for interior architecture and express its "otherness" (Havenhand, 2004, p. 38). This thesis questions whether interior architecture needs domain specific computer aided architectural design (CAAD) software developed solely and specifically for interior architectural requirements. In this framework, it is worth examining whether CAAD software suffices the requirements of interior architecture fully. If not, it shall be examined what may be proposed when constructing a framework for software specific to interior architectural domain.

1.2 Aim and Scope

CAAD software today are mostly developed for general purpose use and then are refined in order to fit one or other professions (Kurman, 1998). The software packages used in interior architecture are developed similarly for general purpose or architectural purpose, not specifically for interior architectural design purposes. These software applications do not seem to meet fundamental requirements of interior architectural practice, since many of the companies utilize different and

individual packages. Yet, an agreement on specific interior architectural domain software has not been established. As a result, every company whether develops a new software package from scratch and/or customizes a general purpose CAAD software by integrating plug-ins to them (Eastman, 1999). Thus, there are plenty of software packages that are seemingly causing a chaos in interior architectural practice.

Although various domain specific software packages are utilized in practice, none seems to be extensively utilized in education. The students are still using general purpose or architectural software while developing their projects. Furthermore, students who are learning to use general purpose software often have difficulties when they begin working in such companies.

This thesis presents an analysis of CAAD software used in interior architectural education and practice, studying the adequate and inadequate aspects of the commonly used CAAD software. Based on these analyses, it is aimed to propose a model for establishing domain specific software for interior architectural design purposes.

1.3 Context and Structure of the Thesis

This thesis comprises a critical analysis of commonly used software in interior architecture and establishes a model that combines the adequate aspects of general purpose and domain specific software, along with user needs gathered from questionnaire and interview analysis.

This study consists of five chapters and further chapters of the thesis are organized as follows:

In the second chapter, entitled "Computer Aided Architectural Design", overall information about CAAD is given. First, the development of CAAD parallel to the development of computers is represented. Here, CAAD software are classified as general purpose and domain specific. Then, the use of computers in interior architectural design and how it affected the way architects and interior architects work are explained. Lastly, the CAAD software used in interior architecture are discussed within the previously introduced classifications.

The third chapter which is entitled as "Critical Analysis of CAAD Software Used in Interior Architecture" contains the analysis part of the thesis and comprises of two main parts. In the first part, comparative analysis of software packages are specified including detailed analysis of CAAD objects and operations used in CAAD software, and analysis of features of general purpose and domain specific software. General purpose CAAD software that are selected and analyzed are AutoCAD[1], 3D Studio[2] MAX and ArchiCAD[3] in terms of their being produced by the leading companies in 2D drawing, 3D modeling and building information modeling (BIM), and also being the most commonly utilized packages in the world and especially in Turkey. Moreover, domain specific CAAD software, such as Giotto, Arcon[4] and WebDekor[5]

[1] AutoCAD is a registered trademark of AutoDesk.
[2] 3D Studio MAX is a registered trademark of AutoDesk.
[3] ArchiCAD is a registered trademark of GraphiSoft.
[4] Arcon is a registered trademark of Eleco.
[5] WebDekor is a registered trademark of Virtual Décor.

are chosen for their different purposes of use in interior architecture; such as kitchen, bathroom and ceramics design. In the second part, analyses of the user preferences are examined. These analyses include questionnaires with the students and interviews with the professionals. The assumptions over students and professionals, sample groups and contents, and the findings of the questionnaires and interviews are also given.

The fourth chapter of the thesis, entitled “Proposed Model”, covers the features and quality attributes of the proposed model. In this chapter, based on the previous analyses and findings, an extensive model is developed and introduced. The presentation of the model is followed by discussions, where a self-assessment about the proposed model is made.

The final and conclusive chapter of the thesis highlights the important points of the analysis, the gathered data and the proposed model. The contribution of this study to literature and suggestions for further work are mentioned here. This chapter is followed by a list of references and appendices. The appendices include the questionnaire and interviews, and present the information about the general purpose and domain specific software packages used in interior architectural education and practice.

2. COMPUTER AIDED ARCHITECTURAL DESIGN

Computer aided architectural design (CAAD), as a term, is a bridge between computers and architecture while emphasizing the use of computer aid in architecture. Computers are used as tools and as media in various disciplines. Architecture is one of these disciplines within which the effects of computers are seen widely. Although the use of computers in architecture is new, compared to many other tools, the impacts and the consequences have varied the way architectural design progresses (Coyne, 1992).

2.1 Development of CAAD

The development of the computers dates back to 1940s. First computers were slow, large and expensive to buy, and were designed especially for commercial use only. There were lots of efforts to make them affordable and widespread. For instance, in 1959, with the invention of the transistor and chip, computers became smaller, faster and reliable (Woodward & Howes, 1997). These innovations fastened developments and in 1970s, the personal computers (PC) were developed. PCs were soon used in different professions, in various offices or even homes because of its smaller size, usefulness in accomplishing everyday tasks and affordability (Kalay, 2004). Furthermore, in the late 1980s, with the advent of Intel, which transformed the poor

graphics of the old computer systems with good quality graphics, the costs of the PCs dropped while affecting the affordability of PCs to explode (Eastman, 1999). The development of the computers has never stopped and computers today are in almost every tool we used.

In the past, architects were limited to the straight lines and arcs of circles with the traditional tools like parallel bars, triangles, compasses, scales and protractors (Mitchell, 1999). The developments in the information technology also influenced the way architects, interior architects and designers worked. Instead of using the traditional tools, computers were utilized in architectural offices due to their efficiency. Computers were first used as a drafting tool primarily to increase the efficiency of conventional modes of production (Silver, 2006).

However, it took a long time for architects to employ computers as a design medium during their design process. According to Straub (1986) there were three issues affecting the use of computers in architectural design. The first two issues, 'cost' and 'time', he claims, slowed down the use of computers. At first, computer technology was new and expensive to buy, therefore only few architectural offices afforded to buy and use it properly. Moreover, architects had to gain architectural computer skills which were difficult and time consuming. The third issue was 'quality', which increased computer use in architecture. Architects started to use computers to improve the quality of the drawings. However, the use of computers in architecture, replaced hand drawings by 3D models and computer visualizations while allowing new architectural forms to emerge (Mitchell, 1999).

In spite of the situation in the architectural practice, computers were of more interest in the academic field. There were various attempts to improve the computer aid in architecture. The leading attempt was Sketchpad which can be considered as the first architectural software. Sketchpad was developed by Ivan Sutherland in MIT in 1963 (Sutherland, 1963) and it is considered to be one of the important milestones in the emergence of CAAD and CAAD software. Sketchpad system made the communication between 'man' and 'machine' easier by strengthening and correcting the lines, intended to draw, with several functions and constraints. Most of the currently used CAAD systems have developed in similar ways to Sketchpad.

Computers and CAAD software have lead to different discussions in both academia and practice. One of the most important discussions is whether computers are solely used as design tool for drafting and modeling purposes instead of traditional tools, or they are used as design media assisting the design activity (Gero, 1986). Some researchers as Coyne (1992) stated that computers had minor effect on design activity but they were commonly used as a design tool for drawing documentation and 3D visualization. This might be valid for the first years of computer use in architecture but today the situation is different. Currently, researchers claim that computers are not only tools but also design media to help designers during project design. As Mitchell (1999) mentioned, computers produced a revolution in design, by allowing architects to imagine, develop, and explore innovative concepts that have proved to be impossible in the past.

Another discussion in the academia is related to the usage of CAAD software in the design process. Architects are separated into two groups with different views. One

group supports the use of CAAD software and its benefits, while the other group thinks the CAAD software is not useful during project design. Woodward and Howes (1997) support the use of CAAD software in architecture and mention benefits of CAAD software which include the following issues;

> Drawings can be prepared more quickly with the computers and the information loaded on a single computer drawing contains more information than a hand drawn one could. Furthermore, computers provide a more systematic way of working, the paper print of a drawing produced with a computer may look more elegant and detailed than any drawing produced by hand could be. Lastly, the files of drawings can more easily and more quickly be sent to consultants or contractor than its paper counterpart could be (p.91).

Another group of researchers think that CAAD software is unbeneficial in architectural design as Turk (2001). Turk stated four reasons for unbeneficial use of CAAD software in some design projects:

> First, in terms of representation, the predetermined computer objects limits designers' creativeness. Second, in terms of situatedness, designers' being in an "artificial world" affects the designers' perception in a negative way. Third, in terms of communication, computers restrict the information flow between the actors in the design process. And last, in terms of particularism and holism, it is hard to get design parts as a whole on the computer.

Even though computers and CAAD software have lead to different discussions, computer use has increased within the past few years and different CAAD software were developed for various purposes of use in architecture.

2.2 Use of CAAD Software in Architecture

In architecture and interior architecture, CAAD software are used for several purposes, such as; documentation, specification writing, drafting, two dimensional drawing (2D), three dimensional (3D) modeling, animation, etc. (Coyne, 1992). Until

1970s computers were not widespread and were barely used for calculation and documentation. In 1970s, architects and designers used the available computers and CAAD software for only specification writing and drafting purposes due to computer's accuracy and speed. In 1980s, several companies like Autodesk, VersaCad, Summagraphics, Microstation, and others released software that supported drafting aspects of architectural design (Kalay, 2004) while augmenting the computer use in architecture.

Also, the developments in the computer technology affected the use of CAAD software in architecture. Once employed as pure 2D drafting systems, when architects met with simple 3D shapes and forms, and elementary rendering features, they began using CAAD software not only for drafting, but also for modeling purposes. Additionally, at the end of 1980s, several modeling features such as 'smooth shading', 'shadow casting' and 'solids modeling' features, distinguished CAAD software from only being drafting systems (Richens, 1992). Furthermore, 1990s brought the general affordability of 3D modeling, rendering, animation and multimedia presentations (Schmitt, 1999). Nowadays, computers are almost indispensible parts of design and presentation phases of architecture.

2.3 Classification of CAAD Software

Despite the context of this study covers a categorization of CAAD software as 'general purpose' and 'domain specific', it is worthwhile to classify CAAD software based on modeling methods such as 'geometrical', 'parametrical' and based on

'building information modeling' (BIM) to understand the development of 3D modeling methods and the terms that are mentioned in this study.

In the 1970s, the development of CAD software took two different routes: 'geometric modeling route' which supports mainly the needs of mechanical engineering applications in the automotive and aerospace industries; and 'building-specific route' which supports the needs of the construction industry (Kalay, 2004).

To start with, 'geometric modeling' is the simplest form of modeling approach which includes *wire frame modeling*, *surface modeling* and *solid modeling*. Firstly, *wire frame modeling* is the oldest computational representation of geometric forms in which the shapes are represented by a collection of the edges and vertices of the shapes represented, leaving to the viewer the task of inferring the volume and other properties of the shape from these outlines (Mantyla, 1982; Kalay, 2004). Wireframe models are easy to use but weak in the representation of objects in terms of well-formedness, generality and completeness (Kalay, 2004). Secondly, *surface modeling* is based on wireframe models that could later be patched by the surfaces. The objects created with *surface modeling* method includes only the surface representations of the 3D object and if cut, it exhibits its empty interior and interiors of the faces which it is composed of (Woodward & Howes, 1997). Surface modelers are especially developed in order to expand the surface properties such as its smoothness. However, since most of the *surface modeling* software did not assist most CAAD operations, another modeling method is developed. In the late 1970s, *solid modeling* method is developed to build complex volume enclosing sets of surfaces with 'boolean operations' (union, intersection and subtract) from simpler solid objects (Whitted,

1982; Sacks, Eastman, & Lee, 2004). *Solid modeling* is the most enhanced *geometric modeling* method which provides accurate representation of a 3D shape, by derivation of any shape measurements, by cutting of sections and by automatic dimensioning features (Sacks, Eastman, & Lee, 2004). Even now, most of the CAAD systems developed for Architecture, Engineering and Construction (AEC) industry make use of *solid modeling* method (Eastman, 1999), like one of the major CAAD software package, AutoCAD.

Although 'geometric modeling' opens up new alternatives and ways of working in architectural design, there are also several problems in using this method. The main problem is the spatial coordinate system which every geometrically defined object based on (Saitz, 2005). For instance, if there appears a change in the design, the user has to revise major sections of the drawing or draw the entire drawing from scratch. This process of revising a solid model is a tedious process and also, defining a 3D solid shape requires more effort than defining its equivalent 2D representations (Sacks, Eastman, & Lee, 2004). These given drawbacks about 'geometric modeling' lead to a new modeling method, 'parametric modeling' to emerge.

'Parametric modeling' is simply rooted in 'geometric modeling' with extending its ease of use and usually utilized in mechanical engineering and building design. "A parametric model is defined by the rules and constraints, which define different aspects of the building and their relationship to each other" (Katz, 2007). Therefore, the geometry identified in the 'parametric modeling' has strong links with its dimensions and parameters (Saitz, 2005). For this reason, when the parametric value of an object changes, its geometry automatically updates. The most important feature

in ‘parametric modeling’ is non uniform rational B-Spline (NURBS) which is used to generate curves and surfaces (Monedero, 2000). This feature is beneficial for the users to model an object more efficiently and in a considerably lower time.

Being a successful modeling method, ‘parametric modeling’ also possesses some difficulties. The employment of ‘parametric modeling’ software has not been widespread until recently, due to its being perceived as highly sophisticated and expensive software (Hernandez, 2006). The highly sophisticated nature of the ‘parametric modeling’ really creates a big difficulty to users and decreases its efficiency during the modeling process. As the drawing becomes more complex, the number of the parameters and the geometric constraints that should be defined becomes extensive (Lee, Sacks, & Eastman, 2006) and difficult to cope with.

Catia[6] and 3D Studio Max can be given as the sufficient examples of ‘parametric modeling’ method. Although AutoCAD is a geometric modeling tool, with the available parametric engines developed specially for AutoCAD, it can be used parametrically.

As the computer technology developed to support extensive parametric inputs, BIM emerged based on ‘parametric modeling’. BIM supports building components, their behavior and relation to each other. This is a new modeling method, used in AEC industry from conceptual design to construction phase while improving the collaboration between architects and engineers.

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[6] Catia is a registered trademark of Dassault Systemes.

In addition, BIM is an extensive modeling method which involves different aspects in a building that needs to be modeled; first the building components, such as walls, doors, etc. and then, abstract geometrical concepts to use in early design phases (Eastman, 1999). BIM provides various advantages in terms of 'productivity', "the ability to rapidly generate design alternatives at different levels and elimination of errors that result from the disparity between different drawings in current practice" (Sacks, Eastman, & Lee, 2004, p. 291). Revit[7] produced by Autodesk and ArchiCAD by Graphisoft are considered to be the forerunner software packages in BIM.

The emergence of 3D modeling methods has offered new ways of working and presentation skills to designers. The foundations are laid with geometric modeling and are developed into the BIM method which is supporting the design process and collaboration between professionals. BIM will surely continue to develop while proposing innovative ideas for architectural design.

Within this framework, the existing CAAD software may be further grouped according to their purpose of utilization as 'general purpose' and 'domain specific' software.

2.3.1 General Purpose Software

General purpose software comprise software packages that are developed to be useful in a wide range of tasks or requirements. They can be adapted to different

[7] Revit is a registered trademark of AutoDesk.

fields, such as; architecture, engineering, etc. As Richens (1992) defines, the general purpose software understand lines and circles, text, raster images and also, in some cases, 3D forms such as; planes, surfaces or solids. However, they have low intelligence about buildings or architecture, but they are highly flexible software which means the same software can be adapted to a building, a landscape or a ship (Richens, 1992). A typical example of general purpose CAAD software is AutoCAD, which is helpful in building design, architecture, landscape architecture and mechanical, civil, electrical engineering fields.

2.3.2 Domain Specific Software

Domain specific software comprise software packages that are developed to be useful for a specific kind of task or requirement. They are simply developed by the specialization of general purpose software to meet the needs of a specialized field in the market.

Until 1980s various software are developed as CAAD packages, most of them being general purpose software. Then, some companies started to develop special features and software for particular fields. (Eastman, 1999). This process led to software specialization, resulting in the domain specific software to emerge.

One of the best examples of the leading companies that develop domain specific software is Graphisoft, with its architectural domain specific software package ArchiCAD. The architectural elements ArchiCAD deals with are slabs and walls, doors and windows, roofs and roof lights which make it more flexible compared to domain specific software but less flexible (Richens, 1992). In this study however, it

is presumed that a domain specific software package implies only the interior architectural domain specific software.

2.4 CAAD Software used in Interior Architecture

There are plenty of different software packages used in interior architecture from 2D drawing to 3D modeling that support different phases of design process. Even the software used in the interior architectural education and practice differ. While the students employ the general purpose CAAD software for 2D drawing and 3D modeling purposes, it is prominent that professionals utilize the domain specific software that are developed for each company most of the time.

The following parts of the study covers the most commonly used general purpose and domain specific software packages in education and practice.

2.4.1 Commonly used General Purpose Software

In this thesis the software packages analyzed as commonly used general purpose CAAD software are AutoCAD, 3D Studio Max and ArchiCAD. These packages are chosen because they are produced by the leading companies in 2D drawing, 3D modeling and BIM, and they are also the most commonly utilized packages in the world and especially in Turkey. The detailed background information about these software packages and their features are given in the following sections.

2.4.1.1 AutoCAD

AutoCAD is a full-featured general purpose CAAD software application for 2D and 3D design and modeling by AutoDesk Inc. AutoDesk released the first version of AutoCAD in 1982 for PCs (AutoCAD, 2007a).

AutoCAD evolved from a very basic version that allows its users to draw only some primitives like lines, polylines, circles, arcs and text. It is also released as AutoCAD LT which is less featured or scaled down to spread the common use of AutoCAD for any 2D drawing facility with a fair price. Today, AutoCAD has a full set of solid modeling and 3D tools but, it still lacks some of the more advanced capabilities of solid modeling applications.

AutoCAD is varied by some vertical programs which address specific areas of interest for diverse markets, such as AutoCAD Architecture, AutoCAD Electrical and AutoCAD Civil 3D (AutoCAD, 2007a). For instance, AutoCAD Architecture allows architectural designers to draw customized 3D objects such as walls and doors. Therefore, architectural designers do not utilize primitive objects unless any particular reason arises. Similarly, AutoCAD Civil Design, AutoCAD Mechanical, AutoCAD Electrical, AutoCAD Map 3D are other examples of specific CAAD applications rooted from AutoCAD (AutoCAD, 2007a).

Furthermore, AutoCAD supports a number of application programming interfaces (API) to let developers extend its functionality (AutoCAD, 2007b). There also exists third-party AutoCAD based applications developed by other developers rather than the ones at AutoDesk.

The well-known format DWG is the native format of AutoCAD while DXF (data exchange format) is used for data exchange. Also, AutoCAD uses DWF (drawing web format) to display its files on the internet (Jefferis, Jones, & Jefferis, 2002). AutoCAD has twenty-two stable versions ending with AutoCAD 2008. In addition, AutoCAD 2009 is in still beta version up to date.

2.4.1.2 3D Studio Max

3D Studio Max is a general purpose 3D modeling application and initially developed by Discreet. Then, in 1999 Autodesk purchased Discreet and reorganized it under AutoDesk Media and Entertainment in 2005 (Bartz, 2000).

3D Studio Max is widely used as 3D animation software to create rich and complex design visualizations with outstanding modeling features. Character studio feature lets creators to animate models. Also, 3D Studio Max has various parametric modeling capabilities through advanced modeling methods such as polygon modeling, non uniform rational B-splines (NURBS) and surface modeling (3D Studio MAX, 2007). Models can be created easily by assigning parameters to predetermined objects; boxes, cylinders, planes, spheres, spindles, prisms, etc. Furthermore, it is possible in 3D Studio Max to define streamlined event sequences. In 3D Studio Max terminology it is called as 'dynamics'. For instance, 'particle emission' is a 'dynamic' and it has up to six different types such as *spray, blizzard* and *snow* (AutoDesk 3D Studio MAX, 2007).

A high-quality photorealistic rendering system is provided in many forms. Since 3D Studio Max has flexible software architecture, numerous kinds of renderers can be

plugged into the software. Nonetheless, 3D Studio Max has its own renderer called ‘scanline’ which is a superior method of rendering improved by various features such as global illumination, radiosity and ray tracing (AutoDesk 3D Studio MAX, 2007). The most current version of the software is 3D Studio Max 2008 up to date.

2.4.1.3 ArchiCAD

ArchiCAD is an architectural software application developed by Graphisoft and initially released in 1982 (ArchiCAD, 2007a). ArchiCAD introduces the concept of smart objects which was not available in other CAAD software applications in 1980s. These smart objects allows user to create buildings with walls, doors, windows and furniture in a parametric fashion meaning that any of these object can be transformed by providing parameters for their object attributes (ArchiCAD, 2007b). It is possible to work with either a 2D or 3D representation. It is fairly easy to switch between 2D and 3D perspectives. All drawing facility is established on ‘virtual building’ essence. A ‘virtual building’ comes along with virtual structural elements. ‘Virtual Building’ is defined by Wallbank (2008) as;

> "Unlike a simple 3D model on a computer, the Virtual Building contains a great deal more information about the building's materials and characteristics. It is a 3D digital database that tracks all elements that make up a building. This information can include surface area and volume, thermal properties, room descriptions, price, specific product information, window, door and finish schedules, and more. ArchiCAD mostly stands for architectural software featuring building information modeling (BIM) experience"

ArchiCAD can import various CAAD software formats such as DWG and DWF to support interoperability with other applications. The newest version of ArchiCAD is ArchiCAD 11 up to date.

2.4.2 Commonly used Domain Specific Software

The commonly used domain specific software that are selected are Giotto, Arcon and WebDekor respectively. These packages are chosen because they represent different purposes of domain specific software used in interior architecture; such as kitchen, bathroom and ceramics design. Giotto is one of the oldest examples of software utilizing geometric modeling and Arcon is an example of software utilizing a parametric modeling technique. WebDekor differs in being a web based software package.

2.4.2.1 Giotto

Giotto is a domain specific software package developed by an Italian Firm in order to fulfill specific needs of Lineadecor, which is a specialized company in kitchen furniture and accessory design with its several branches in Turkey and Europe. Giotto can be considered as an initial example of the software packages providing geometric modeling. However, Giotto did not develop along with the technical improvements and was defeated with the new improvements in CAAD technology. Thus, Lineadecor switched off to another software package by mid 2007.

On the other hand, Giotto has the capability to be adapted for different companies in the practice. It has its own CAAD engine but if a plug-in supporting the pre-defined object libraries of the company is installed into, it becomes a specialized software for that specific company. Similarly, if new objects are required to be included in its object library, a new plug-in may be installed.

Due to the limited information about Giotto, its basic properties and features are depicted in accordance with the experiences of the author.

Initially, Giotto has a limited user interface at the beginning which includes the main menu. This menu directs the user to the main functions of Giotto including ‘design’, ‘3D representation’, ‘cost estimation’, ‘printing options’ and ‘other’ functions such as; software configuration, its update and language.

The user who wants to design a kitchen first selects the ‘design’ function from the main menu to prepare the 2D drawings. Then, a new empty page opens with several features existing on the toolbar. These toolbar on the upper side of the page includes ‘file’, ‘view’, ‘wall’, ‘active wall’, ‘layers’, ‘modules’, ‘menu’, zoom’ and various other features. Also, the list ‘listino’ that is placed on the left side of the page includes the pre-defined kitchen modules. The first step in the design phase is to form the walls of the kitchen based on the exact dimensions in millimeters. Next, the other building elements like columns, beams, doors and windows have to be prepared. However, only walls are determined as a building component, column and beam representations in Giotto simply consist of rectangular blocks which is determined by the user defined parameters. Also, windows and doors are considered as accessories and represented under the ‘listino’ menu. To place any of these elements one has to first identify on which wall these items will be placed and then has to move the element into its correct place. Afterwards, the design process starts with placing objects, starting from kitchen modules, countertops, electrical appliances and accessories into the proper places. If ceramic covering are needed to be placed or the dimensions (height, length, width) of the modules or objects height,

length, width are needed, the menu toolbar includes the features as ‘hatching’ and ‘dimensioning’ on the top of the page. The user is limited to make modifications only in 2D front and top view of the drawing. The 3D perspectives can be taken here but it is not allowed to make any modifications there. Moreover, there is no ‘undo’ feature in the Giotto. Thus, in the case of a change or ‘undo’ situation, users either have to start from scratch or start from another saved file of the project.

After setting up the 2D drawings, the user has to save and turn back to the main interface in order to realize the project in 3D. From here, by selecting the ‘3D representation’ again a new page opens and Giotto loads the 3D modules of the prepared drawings. Actually, in Giotto all of the objects drawn are 3D, whether it is represented as 2D top view or a perspective. However, the user only has the capability of seeing them in 3D. The materials, textures and colors can be attached to the objects drawn in ‘3D representation’, but, the user can not modify them here. If mistakes made during 2D drawing are realized in this view, or there are changes that needs to be done, these changes has to be done again in 2D drawing. This problem limits the user and extends the design process, which is a big problem especially in the market.

Moreover, in 3D representation menu, one can render the project after assigning the textures and colors, with a real time ray tracing plug-in POV-Ray (POV-Ray, 2008). Again, due to the lack of ‘undo’ command, if the color of the object is wanted to change, the next color is placed upon the old one on the same object. This situation results in the increase of the file size and increase in the duration of the rendering process. When the representation is ready, the 3D images can be printed here. But, to

take 2D drawing printouts, one has to again go back to the main menu and select the plan or side view in an identified scale.

Similarly, to estimate the cost of the project, the user needs to turn back to the main menu and select the ‘cost estimation’ feature. Giotto automatically organizes the objects drawn and the pre-determined cost values of the objects, and gives the total cost of the project. Nevertheless, if the cost of the project appears to be higher for the customer, the project should be drawn again or revised starting from 2D drawings, which means that all of the ‘3D representation’, ‘view’ and ‘cost estimation’ features have to be done again.

Furthermore, if the project is approved by the customer, the projects are then needed to be sent to the factory in order to start with the production. However, since Giotto does not support the collaboration between branches of the company through internet, all the business is done manually.

A typical design process is tried to be illustrated while mentioning the sufficient and insufficient features of Giotto. The insufficient features can be summed up as;

- The limitation in the design process due to the modular design,
- The limitation related to the quality software with its lacking commands and features and with its insufficient translation of language
- The limitation of modification of objects in 3D
- The limitation of collaboration between users
- The limitation of compatibility of the drawing in another software or in another file format

2.4.2.2 Arcon

Arcon is actually is an architectural based general purpose software which is developed by a German software company, Eleco (Arcon 3D Architect, 2006). To prevent the confusion, it is important to state that the Arcon mentioned in this thesis is the Arcon Armadi Art version, which is a domain specific software package developed based on the original Arcon 3D Architect by adding the pre-defined object library of Armadi Art. Armadi Art is a company established in 1974, specializing especially in design of bathroom furniture. Later, Arcon was adapted in early 2007.

Similar to AutoCAD, which is varied by vertical programs in different markets, Arcon is also varied by vertical programs, such as; Arcon 3D Bathroom Designer, Arcon 3D Kitchen Designer, Arcon 3D Home Designer, Arcon 3D Interior Designer, Arcon 3D Home Designer Expert and Arcon 3D Architect (Arcon, 2008).

While designing with Arcon, the design starts with the aid of gridlines and projects can be modeled from ground floor to the roof in detail. Arcon works in a very similar way to ArchiCAD and includes the smart objects as well. The smart objects can be selected from a variety of pre-determined objects such as; walls, roofs, staircases, windows, doors and other elements of construction (Arcon, 2008). Also, with the calculation of light, shade, transparency and mirroring, as well as consideration of the position of the sun and the moon, a photorealistic presentation can be obtained (Arcon 3D Architect, 2006). The ‘cost estimation’ feature, which may be assigned to each object, makes the design and presentation of the project easier.

There are available plug-ins, object and texture libraries on the Arcon's web page for the users who want to extend their use (Arcon, 2008).

2.4.2.3 WebDekor

WebDekor, as its name indicates, is a web based domain specific software developed by Virtual Décor (3D Web, 2008) for Çakmak Yapı, which is the distributor of Aparichi ceramics in Turkey. WebDekor can be used for different purposes in interior design; especially in office, bathroom and kitchen design with different types of furniture and also with wall and floor coverings.

WebDekor is a free and an user friendly software package (3D Web, 2008) that can be learnt in a short time with the help of the directions while drawing. The pre-determined object library is not extensive like the other domain software packages. However, it includes the entire texture library derived from Aparichi ceramics.

While designing with WebDekor, initially the floor plan is defined with its walls. Then, the objects are placed with the built-in object library. All the objects drawn are in 3D and they are smart objects that can easily be modified by the user. Also, WebDekor provides navigation in 3D with user-defined views. After the objects are placed, the user can arrange which wall or floor tile to use with relevant design, positioning and number. Being an interactive software package provides various advantages for WebDekor, such as providing information about; the state of the ceramic stocks in Turkey, the number of ceramics to be ordered and the price of these orders. Moreover, it maintains collaboration between the different branches

within a company. WebDekor is a significant example among the domain specific software analyzed and gives clues about how the software will be like in the future.

3. CRITICAL ANALYSIS OF CAAD SOFTWARE USED IN INTERIOR ARCHITECTURE

In this chapter, firstly CAAD objects and operations are defined, and features of the previously introduced general purpose and domain specific CAAD software used in interior architecture are examined according to these classifications. Then, in the analysis of user preferences part, the analyses gathered as a result of questionnaires and interviews are discussed.

3.1 Comparative Analysis of Software Packages

The comparative analysis of software packages covers the analysis of CAAD objects and operations, and analysis of general purpose and domain specific software in detail.

3.1.1 Analysis of CAAD Objects and Operations

The analysis of CAAD objects and operations are best identified by Szalapaj (2001) in his book “CAD Principles for Architectural Design”. The following issues cover the issues of CAAD objects and operations in detail.

3.1.1.1 CAAD Objects

As stated by Szalapaj (2001), CAAD objects are categorized under two main headings, 2D objects and 3D objects. 2D objects include ‘lines’, ‘grids’, ‘2D symbols’ and ‘dimensions’ (Figure 3.1). Firstly, ‘a line is a one-dimensional entity whose extend is designated by length that may exist in a one, two or three dimensional space’ (Eastman, 1999, p. 179). ‘Lines’ create a basis for basic geometries and shapes, such as polylines, rectangles, polygons, circles, arcs and curves. Secondly, ‘grids’ are used to define guidelines on the drawing surface and they are especially required when forming the building construction system. Thirdly, the ‘2D symbols’ are the representations of a complex object that are used repeatedly in a drawing whether they are created by the users or imported from the object libraries. For instance, architectural ‘2D symbols’ include door, window, sink, toilet, etc. symbols. The last item in the 2D objects is ‘dimensions’ with which the accurate measurement of the lines, the angles and the distances are calculated.

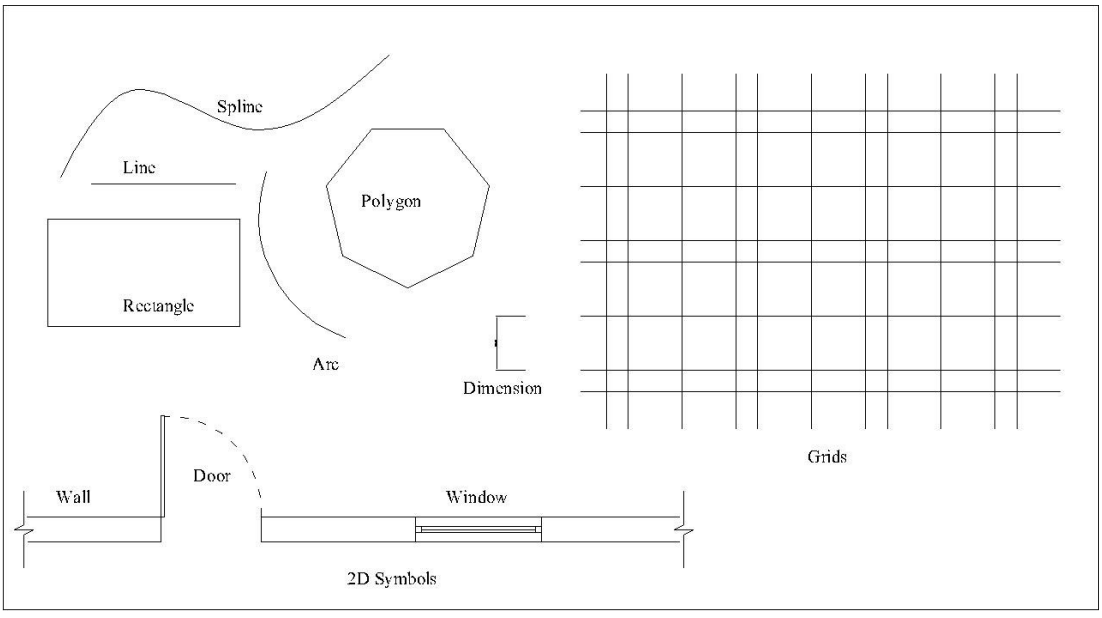

Figure 3.1 2D CAAD objects

3D objects include ‘planes’, ‘volumes’, ‘quadric surfaces’ and ‘3D symbols’ as Szalapaj (2001) mentioned (Figure 3.2). To begin with, ‘planes’ are defined with three non-collinear points that are flat and are constructed simply by creating a 2D form and extruding this form. Next, ‘volumes’ are drawn by providing parameters like length, width, height, radius to predetermined 3D volumes existing in most of the CAAD software. Some of the examples of ‘volumes’ include; blocks, spheres, hemispheres, cones and cylinders. ‘Quadric surfaces’ are generated from conic sections which are the 2D shapes formed when a plane cuts a cone at various angles. Later on, these sections are rotated 180 degree through an axis while generating a surface. Spheres, ellipsoids, hyperboloids and paraboloids are some of examples of these 3D objects (Szalapaj, 2001). Finally, ‘3D symbols’ are similar to 2D symbols and mostly created by users. While these symbols reduce the memory size of the models, each symbol can also carry additional information about their cost, size, etc (Szalapaj, 2001).

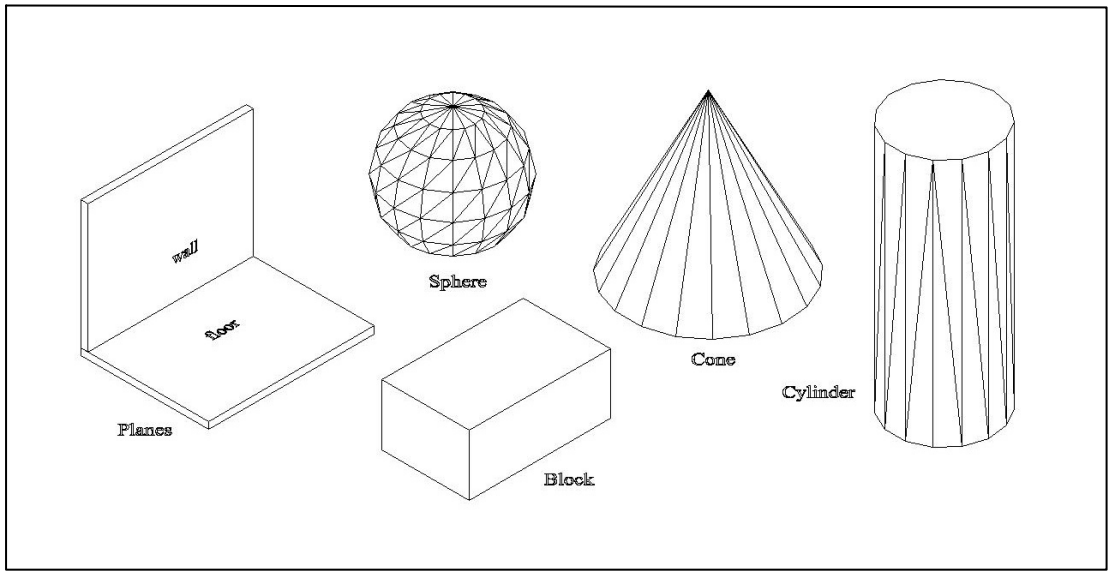

Figure 3.2 3D CAAD objects

The objects that are defined by (Szalapaj, 2001) are noteworthy ones in constituting a framework for the analysis of CAAD software and the proposed model in this study.

3.1.1.2 CAAD Operations

CAAD operations are categorized into four main groups as ‘geometric transformations’, ‘topological transformations’, ‘boolean operations’ and ‘logical operations’ (Szalapaj, 2001).

‘Geometric transformations’ modify the properties of the objects, such as shape, coordinates or angle, apart from its topology. ‘Move’, ‘rotate’, ‘scale’, ‘reflect’ and ‘shear’ transformations are some of the examples. As Szalapaj (2001) remarks ‘move’ transformation relocates a selected object to a specific distance. Next, ‘rotate’ transformation changes the objects’ angle into the specified angle. Similarly, ‘scale’ transformation modifies objects’ size into a higher or lower scale. Then, ‘reflect’ transformation (or well known as mirror transformation) mirrors an object through an axis while protecting the original shape and size. On the other hand, ‘shear’ transformation produces a distortion on the selected object while maintaining its topology.

The second CAAD operation ‘topological transformations’ allows for changing the object’s topology and its spatial features that are connected to each other. The ‘topological transformations’ are also effective in providing more complex shapes out of simple geometric forms (Eastman, 1999). ‘Extrude’, ‘sweep’ and ‘loft’ transformations are the examples of ‘topological transformations’ given by Szalapaj (2001). ‘Extrude’ is an operation which transforms 2D objects into 3D by forcing

out the plan view of the object into a specified height. Nowadays, ‘extrude’ is the most common ‘topological transformation’ used in most of the CAAD software. Moreover, ‘sweep’ is a method that creates a geometrically complex 3D object through pushing a 2D object through space while revolving it around an axis at the same time (3D Animation Glossary, 2008). As a last ‘topological transformation’, ‘loft’ denotes creating a 3D surface by copying a 2D section through an axis (Wikipedia, 2008). This method is mostly applied by 3D modeling software packages.

‘Boolean operations’ are the basic operations in any CAAD software. ‘Boolean operations’ include ‘add’, ‘subtract’ and ‘intersect’ operations (Szalapaj, 2001). The ‘add’ operation unifies two or more objects while creating an object based on the total geometry of all. The ‘subtract’ operation, as the name implies, subtracts the selected object from another by creating an object from the remaining geometry. The ‘intersect’ operation creates an object from the overlapping geometry (MYCADSITE, 2008)

The last operation Szalapaj (2001) defined is ‘logical operations’ that includes ‘grouping’, ‘typing’ and ‘layering’ operations. Initially, ‘grouping’ operation provides grouping of 2D or 3D objects as if they react like one object. Then, ‘typing’ operation is a process of grouping objects with similar characteristics to describe a drawing in terms of its parts such as walls, windows, etc. As indicated by Szalapaj (2001), ‘types’ in CAAD systems are associated with non-graphical information such as area, cost, value, etc. that allow users to control the drawing information for other purposes. Moreover, ‘types’ are the focus points in object oriented programming

(Eastman, 1999). The last ‘logical operation’ is the ‘layering’ that helps to organize drawings in different layers of information, put on top of each other like transparencies.

Like the CAAD objects defined, these CAAD operations are useful in building a framework for the analysis of software packages and proposed model as well.

3.1.2 Analysis of Features of CAAD Software

Features of CAAD software are analyzed depending on the classification made by Szalapaj (2001). As the classifications of CAAD objects and operations, and items mentioned there do not satisfy all the features in general purpose and domain specific CAAD software packages examined, new items are added and the categorization is made under five main features. Initially, ‘drawing’ features include the detailed list of CAAD objects defined in the previous chapter. For instance, architectural, engineering and landscape symbols are added to 2D and 3D symbols in this study. Secondly, ‘transformation’ features are formed with the extended list of ‘geometrical’, ‘topological’ and ‘boolean operations’. Next, ‘view’ features which are not mentioned by Szalapaj (2001), are significant features in CAAD software packages and the selected software packages are also analyzed for their ‘view’ features. Moreover, ‘rendering’ features, which are also lacking in the CAAD operation analyses, involve enriched ‘material’, ‘lighting’ and ‘rendering’ features. Final feature in the analysis of features of CAAD software is the ‘other’ features that basically contain the ‘logical operations’ and the new features in the software packages analyzed.

Further parts of this study also examine the commonly used general purpose and domain specific CAAD software respectively in the light of these feature classifications.

3.1.2.1 General Purpose CAAD Software

General purpose CAAD software packages that are analyzed in this chapter are AutoCAD, 3D Studio Max and ArchiCAD. As previously mentioned, these packages are chosen because of their common usage and their long market experience over specific areas in architecture and interior architectural field, such as 2D drawing, 3D modeling and BIM. These software packages are evaluated here in relation to their 'drawing', 'transformation', 'view', 'rendering' and 'other' features correspondingly.

Firstly, in the Table 3.1, the comparison of 'drawing' features in general purpose CAAD software is shown. This comparison points out that ArchiCAD is the most comprehensive software package in terms of its improved 'drawing' features.

Table 3.1 Comparison of ‘drawing’ features in general purpose CAAD software

			AutoCAD	3Ds Max	ArchiCAD
DRAWING	2D Objects	Line Types	*	*	*
		Shapes	*	*	*
		Grids	*	*	*
		Dimension	*		*
	2D Symbols	Architectural	*		*
		Engineering	*		*
		Landscape	*		*
	3D Objects	Planes	*	*	*
		Volumes	*	*	*
		Quadric Surfaces		*	
		High-Order Surfaces		*	
	3D Elements	Architectural			*
		Landscape			*

Secondly, ‘transformation’ features, which are classified as ‘geometric’, ‘topological’ and ‘boolean’, are given in detail in Table 3.2. It is important to state that here the ‘geometric transformation’ list is extended and ‘3D geometric transformations’ and ‘geometric deformations’ such as ‘bend’, ‘taper’ and ‘twist’, are integrated into this list.

On the contrary to drawing analysis, in transformation features, 3D Studio Max which is qualified in 3D modeling, meets all the requirements and is the most inclusive software compared to AutoCAD and ArchiCAD. Moreover, the main classifications of terms mentioned in ‘transformation’ features are given in the analyses of CAAD operation part. However, in order to see the detailed definitions of all of these terms, one can refer to ‘List of Terms’ at the end of this thesis.

Table 3.2 Comparison of 'transformation' features in general purpose CAAD software

			AutoCAD	3Ds Max	ArchiCAD
TRANSFORMATIONS	Geometric Transformations	Copy	*	*	*
		Mirror	*	*	*
		Array	*	*	*
		Offset	*	*	*
		Erase	*	*	*
		Move	*	*	*
		Scale	*	*	*
		Rotate	*	*	*
		Stretch	*	*	*
		Extend	*	*	*
		Trim	*	*	*
		3D Mirror	*	*	*
		3D Array	*	*	*
		3D Move	*	*	*
		3D Rotate	*	*	*
	Geometric Deformations	Bend		*	
		Taper		*	
		Twist		*	
	Topological Transformations	Extrude	*	*	*
		Sweep		*	
		Loft		*	
		Wave		*	
		Noise		*	
	Boolean Operations	Union	*	*	*
		Subtract	*	*	*
		Intersect	*	*	*

‘View’ features are grouped as 2D and 3D view (Table 3.3). ‘2D view’ involve ‘zoom’, ‘pan’, ‘2D wireframe’ and ‘2D hidden’ view, various ‘viewports’ (top, bottom, left, right, front, back and user defined viewports) and ‘2D section’ view features. ‘3D view’ feature list is more detailed compared to ‘2D view’ list, in order to provide a proper the perception of the object or project to the user in the third dimension. Thus, ‘3D view’ feature consists of ‘3D wireframe’, ‘3D hidden’, ‘3D shaded’, ‘perspective’, ‘axonometric’ view, ‘3D section’ view, ‘3D orbit’, different ‘camera’ views and ‘animation’ features. Among other general purpose software, ArchiCAD, which is architectural based software, embraces most of the features as emphasizing the importance of view features in architecture.

Table 3.3 Comparison of ‘view’ features in general purpose CAAD software

			AutoCAD	3Ds Max	ArchiCAD
VIEW	2D View	Zoom	*	*	*
		Pan	*	*	*
		2D Wireframe	*	*	*
		2D Hidden	*		
		Viewports	*	*	*
		2D Section View			*
	3D View	3D Wireframe	*	*	*
		3D Hidden	*	*	*
		3D Shaded	*	*	*
		Perspective	*	*	*
		Axonometric	*	*	*
		3D Section View			*
		3D Orbit	*	*	*
		Camera	*	*	*
		Animation		*	

Next feature is related to ‘rendering’. These features consist of material library and operations, lighting elements and operations, and rendering methods (Table 3.4). Here again, 3D Studio Max proves its proficiency in ‘rendering’ features and meets all of the needs given.

Table 3.4 Comparison of ‘rendering’ features in general purpose CAAD software

			AutoCAD	3Ds Max	ArchiCAD
RENDERING	Material Library	Texture Library	*	*	*
		Color Library	*	*	*
	Material Operations	Material Creation	*	*	*
		Material Editing	*	*	*
		Material Import	*	*	*
		Mapping Direction	*	*	*
		Mapping Frequency		*	
		Texture Mapping		*	
	Lighting Elements	Spotlight		*	*
		Direct Light		*	
		Sunlight	*	*	*
		Omni		*	
	Light Editing Operations	Radiosity	*	*	
		Intensity		*	
		Brightness		*	*
		Shading	*	*	*
		Reflection	*	*	*
		Refraction		*	
	Rendering Method	Local Rendering	*	*	*
		Global Rendering	*	*	*

The last feature in general purpose CAAD software analyses are categorized under 'other' feature list. 'Texting', 'hatching', 'dimensioning', and 'calculation' are the new features added to the classification made by Szalapaj (2001). ArchiCAD and AutoCAD as well, are observed to be successful for satisfying the other features illustrated in Table 3.5.

Table 3.5 Comparison of 'other' features in general purpose CAAD software

		AutoCAD	3Ds Max	ArchiCAD
OTHER	Grouping	*	*	*
	Typing			*
	Layering	*		*
	Texting	*	*	*
	Hatching	*		*
	Dimensioning	*		*
	Calculation (area etc.)	*		*

As a result of these general purpose CAAD software feature analyses, it is seen that ArchiCAD is doing well in the 'drawing', 'view' and 'other' features which are mostly serving to the 2D drawing purposes. On the other hand, 3D Studio Max is verifying its proficiency in 3D modeling features such as 'transformation' and 'rendering' features.

3.1.2.2 Domain Specific CAAD Software

CAAD Software concerned and analyzed in this part of the study are Giotto, Arcon and WebDekor, as examples of domain specific CAAD software used in interior architectural practice. This part of the study covers the same procedural analyses as general purpose CAAD software do and the features investigated here are 'drawing', 'transformation', 'view', 'rendering' and 'other' features. Although the lists provided

in this section are based on the same criteria as the criteria used for general purpose software evaluation, they have additional features and some features are totally omitted.

The simplification in the lists provided, is best observed in the ‘drawing’ features. As Table 3.6 indicates, there is a simplification in the 2D and 3D objects list. In order to balance this simplification, software providers enhanced the 2D and 3D symbols used in practice. Furthermore, it can be clearly perceived from Table 3.6 that these three software packages have the capability of drawing the elements in accordance with the specialized design are they are developed for. According to their specialized design area in interior architecture, as it is observed, Giotto is experienced in kitchen design, Arcon in bathroom design and WebDekor in ceramics design.

Table 3.6 Comparison of ‘drawing’ features in domain specific CAAD software

				Giotto	Arcon	WebDekor
DRAWING	2D Objects	Line Types		*	*	*
		Shapes		*	*	
		Grids			*	
		Dimensions		*	*	
	2D Symbols	Architectural		*	*	
		Engineering		*		
		Landscape		*	*	
		Interior	Kitchen	*		*
			Bathroom		*	
			Furniture	*	*	*
			Accessories	*	*	*
	3D Objects	Planes		*	*	*
		Volumes		*	*	*
	3D Elements	Architectural		*	*	*
		Engineering		*		
		Landscape		*	*	
		Interior	Kitchen	*		*
			Bathroom		*	
			Furniture	*	*	*
			Accessories	*	*	*

After the decrease in ‘drawing’ feature lists, significant changes in the ‘transformation’ features draw attention (Table 3.7). While the list involves the simple transformations, complex items in the ‘geometrical deformations’ and the ‘topological transformations’ are decreased considerably. This can be viewed both as an advantage that simplifies the design process in interior architectural practice and also as a disadvantage that affects the creativity of the professionals in a negative manner. Apart from these changes, Arcon meets all of the ‘transformational’ requirements among the three analyzed software due to its being developed as domain specific software package by adding plug-ins to general purpose software.

Table 3.7 Comparison of 'transformation' features in domain specific CAAD software

			Giotto	Arcon	WebDekor
TRANSFORMATIONS	Geometric Transformations	Copy	*	*	*
		Mirror	*	*	*
		Array	*	*	*
		Offset	*	*	*
		Erase	*	*	*
		Move	*	*	*
		Scale	*	*	*
		Rotate	*	*	*
		Stretch		*	*
		Extend		*	
		Trim	*	*	
		3D Array	*	*	*
		3D Move	*	*	*
		3D Rotate	*	*	*
	Topological T.	Extrude	*	*	*
	Boolean Operations	Union		*	
		Subtract		*	
		Intersect		*	

The third feature analyzed is 'view' feature. Since the perception of customers in understanding the designed project and this projects' potential to become realized, are significant factors in interior architectural practice, 'view' features in domain specific CAAD software has nearly an extensive list as general purpose software (Table 3.8). The only items absent here are '2D hidden' and 'axonometric' view features. In the 'view' feature analyses, Arcon is again the most scoring software package.

Table 3.8 Comparison of ‘view’ features in domain specific CAAD software

			Giotto	Arcon	WebDekor
VIEW	2D View	Zoom	*	*	*
		Pan	*		*
		2D Wireframe	*	*	*
		Viewports	*	*	
		Section View	*	*	
	3D View	3D Wireframe		*	
		3D Hidden	*	*	*
		3D Shaded	*	*	*
		Perspective	*	*	*
		Section	*	*	
		3D Orbit	*	*	*
		Camera	*	*	*
		Animation		*	

Moreover, in ‘rendering’ features, although the feature list is extensive, none of the software packages meets all of the items stated. ‘Rendering’ feature analyses in Table 3.9 shows that ‘material editing’ features in Giotto, ‘light editing’ features in Arcon, ‘material editing’ and ‘rendering’ features in WebDekor are weak. Although these domain specific software packages include ‘global rendering’ methods, these methods are not effective in presenting the photorealistic image of the project as in the general purpose software analyzed.

Table 3.9 Comparison of ‘rendering’ features in domain specific CAAD software

			Giotto	Arcon	WebDekor
RENDERING	Material Library	Texture Library	*	*	*
		Color Library	*	*	*
	Material Operations	Material Creation		*	
		Material Editing		*	
		Material Import		*	
		Mapping Direction	*	*	*
		Mapping Frequency	*	*	*
		Texture Mapping	*	*	*
	Lighting Elements	Sunlight	*	*	
		Omni	*		*
	Light Editing	Radiosity	*		
		Intensity	*	*	
		Brightness	*	*	*
		Shading	*	*	*
		Reflection	*	*	
		Refraction	*		
		Resolution	*		
	Rendering Method	Local Rendering	*	*	*
		Global Rendering	*	*	*

Examination of ‘other’ features is the last step in domain specific software feature analyses. ‘Cost estimation’ feature is a remarkable point that makes difference between the domain specific from the general purpose software packages. As Table 3.10 illustrates Arcon and Giotto are the strongest packages fulfilling most of these features provided.

Table 3.10 Comparison of 'other' features in domain specific CAAD software

		Giotto	Arcon	WebDekor
OTHER	Grouping		*	
	Typing	*	*	*
	Layering	*	*	
	Texting	*	*	*
	Hatching	*	*	
	Dimensioning	*	*	
	Calculation (area etc.)	*	*	*
	Cost Estimation	*	*	*

The evaluations of features revealed that Arcon is the most effective package among all the domain specific software examined. Arcon's success comes from its being adapted by a plug-in to domain specific software from a general purpose software package. On the other hand, Giotto seems insufficient in renewing itself along with the developments in technology and WebDekor as a web based software, does not have extensive features. These are the important criteria in affecting the performance of these software packages.

3.1.2.3 Comparison of Features in General Purpose and Domain Specific CAAD Software

In the previous analyses, features of the general purpose and domain specific software are compared for each software group. The following Table 3.11 represents an overview of the comparison of features in the general purpose and domain specific software packages.

Table 3.11 Comparison of features in general purpose and domain specific software

Software Features	**General Purpose Software**	**Domain Specific Software**
Drawing Features	Quadric Surfaces	None
	High-order Surfaces	None
	None	2D and 3D Interior Architectural Symbols
	None	3D Engineering Symbols
Transformation Features	Geometric Transformations as 3D Mirror, Bend, Taper, Twist	None
	Topological Transformations as Sweep, Loft, Wave , Noise	None
View Features	2D View as 2D Hidden	None
	3D View as Axonometric View	None
Rendering Features	None	Light Editing as Resolution
	Lighting Elements as Spotlight and Direct Light	None
Other Features	None	Cost Estimation

The main purpose of these software feature evaluations is to determine the gaps and overlaps of general purpose and domain specific software in order to obtain the interior architectural domain requirements. It is aimed at combining the missing features that are identified with the comparisons and the overlapping features that are determined throughout the analyses in the proposed model.

3.2 Analysis of User Preferences

This study involves a questionnaire with students and an interview with the professionals. The framework of these analyses with users gives detailed information about; the identification of the assumptions, the contents of the questionnaire and interview applied to interior architectural students and professionals, the sample groups these questionnaires and interviews performed, and finally about the results of the findings.

3.2.1 Analysis of Students' Preferences

The assumptions related to students, the content of the questionnaires, the sample groups from students and the results of the findings related to the questionnaire are the issues examined in the following part.

3.2.1.1 Assumptions

The assumptions over students are as following;

1. Interior architectural students utilize general purpose or architectural domain specific CAAD software during their design development.
2. General purpose CAAD software packages are not sufficient in interior architectural design.
3. Interior architectural design students need domain specific CAAD software which support detailed interior architectural requirements (color, lighting, material, furniture, etc.).

3.2.1.2 Questionnaire

Based on the assumptions stated above a questionnaire (Appendix A.1) is performed to obtain information about;

- Students' background information about CAAD software packages used,
- The software packages used in interior architectural design process,
- The distribution of use of software packages in *conceptual, project development* and *presentation phases* and the reasons to use or discontent these packages in that specific phase,
- The sufficiency of general purpose software in interior architectural design,
- The necessity for domain specific software in interior architectural design,
- The need of a new domain specific software in interior architecture,
- The user needs about the new domain specific software.

3.2.1.3 Sample Groups

Junior and senior students studying at the Department of Interior Architecture and Environmental Design in Bilkent University were involved in this study. The 3rd and 4th year students are selected because the 1st and 2nd year students are not experienced in using CAAD software. The questionnaire is performed with a total number of 112 students, of whom 60 were junior students and 52 were senior students. The percentage distribution in Figure 3.3 shows that 19 percent of them are male and 81 percent of them are female students.

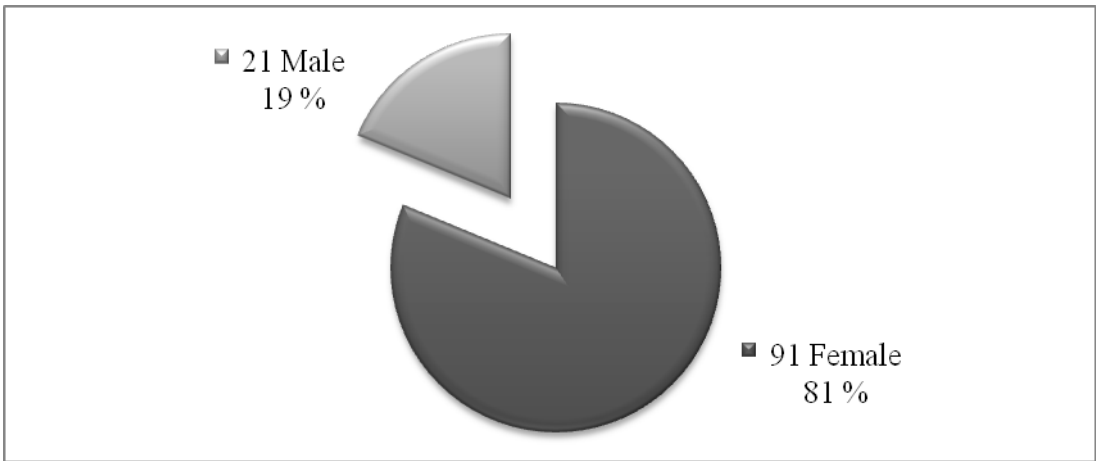

Figure 3.3 Percentage distribution of gender of students

The use of software aid during interior architectural design process is examined through questionnaires. According to the analyses, while 75% of students use software aid, in contrast, 25% does not utilize software aid in their design process (Figure 3.4). Furthermore, it is determined that students have been using computers for 1.7 years on average.

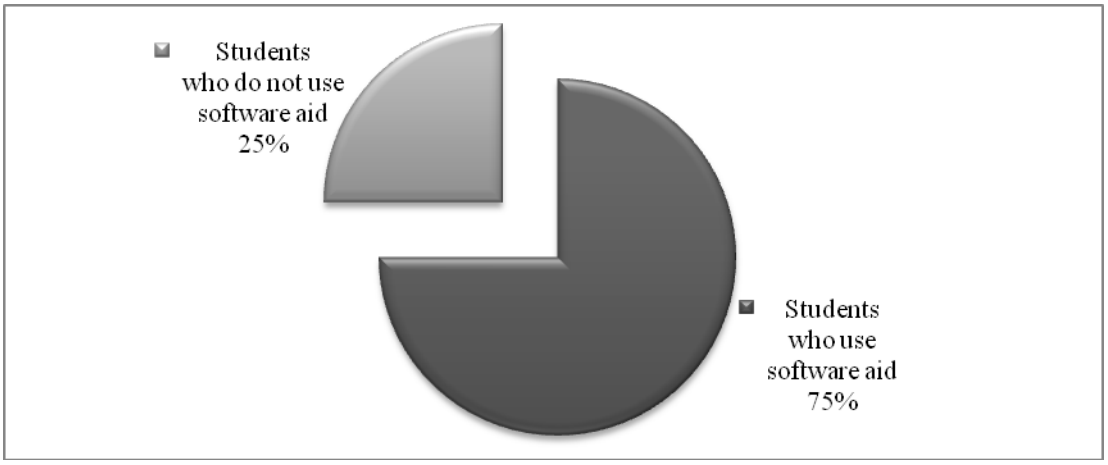

Figure 3.4 Percentage distribution of the use of computers by students

Although 25% of students does not use computers, as Figure 3.5 demonstrates there is a considerable improvement in students' familarity of software throughout their design process. The number of students using computers within 4th class students is 35, this number appears to be 49 in the 3rd year students. Thus, this figure underlines the increase in the use of computers day by day,contributing to the future importance of this study in interior architecture.

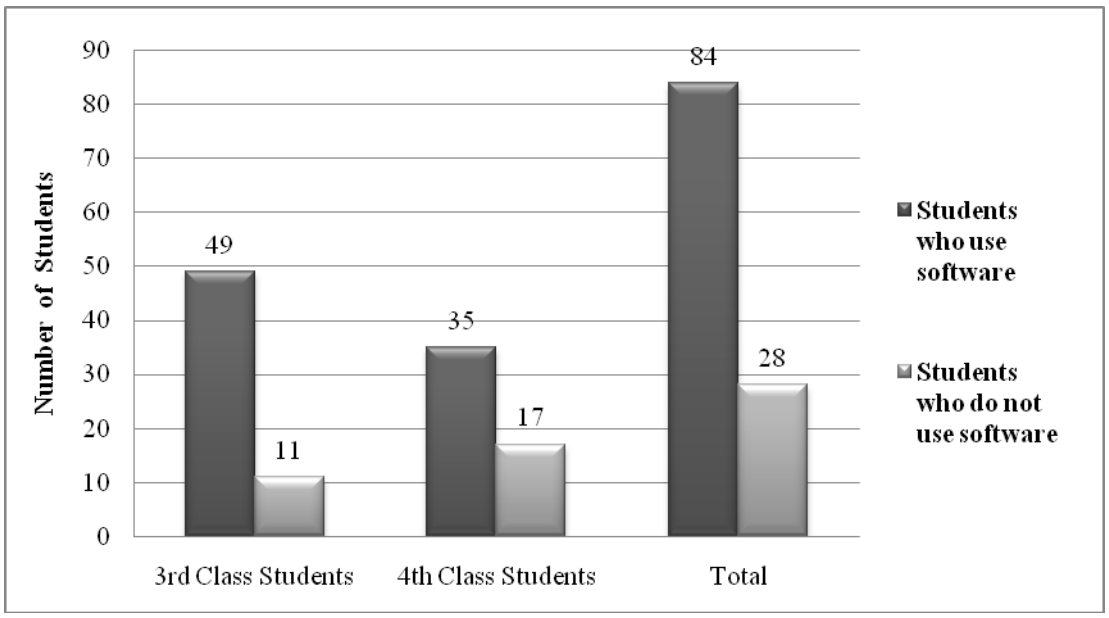

Figure 3.5 Distribution of the use of computers by students

3.2.1.4 Findings

The results of the questionnaire revealed several important points. These points will be explained with the following figures and tables. The contents of the questionnaire that is prepared for the students can be seen in the Appendix A.1.

After collecting information about the students' background in computer use, as stated in the 'assumption 1'(chapter 3.2.1.1) the most common software packages in interior architectural design are revealed respectively as; AutoCAD which is a general purpose 2D drawing and modeling software, 3D Studio Max which is a general purpose 3D modeling software, Photoshop[8] which is a 2D image processing software, SketchUp[9] which is a software supporting conceptual design and ArchiCAD which is an architectural based software (Figure 3.6). Moreover, the 'other' software represented in Figure 3.7 are the software that have 2 percent or lower rates from students and include; Rhinoceros[10], Outline 3D[11], Paint[12], Arcon, 3D Home Architect[13], Illustrator[14], Paint Shop Pro[15], Allplan[16], Corel Draw[17], Carrara[18], Kareo[19], Maya[20], and even Microsoft Frontpage[21] and Acrobat Reader[22].

[8] Photoshop is a registered trademark of Adobe Systems Inc.
[9] SketchUp is a registered trademark of Google.
[10] Rhinoceros is a registered trademark of Robert McNeel and Ass.
[11] Outline 3D is a registered trademark of Parallel Graphics.
[12] Paint is a registered trademark of Microsoft Corporation.
[13] 3D Home Architect is a registered trademark of Broderbund.
[14] Illustrator is a registered trademark of Adobe Systems Inc.
[15] Paint Shop Pro is a registered trademark of Corel Corporation.
[16] Allplan is a registered trademark of Nemetschek Systems.
[17] Corel Draw is a registered trademark of Corel Corporation.
[18] Carrara is a registered trademark of DAZ 3D.
[19] Kareo is a registered trademark of White CAD.
[20] Maya is a registered trademark of AutoDesk Inc.
[21] Microsoft Frontpage is a registered trademark of Microsoft Corporation.
[22] Acrobat Reader is a registered trademark of Adobe Systems Inc.

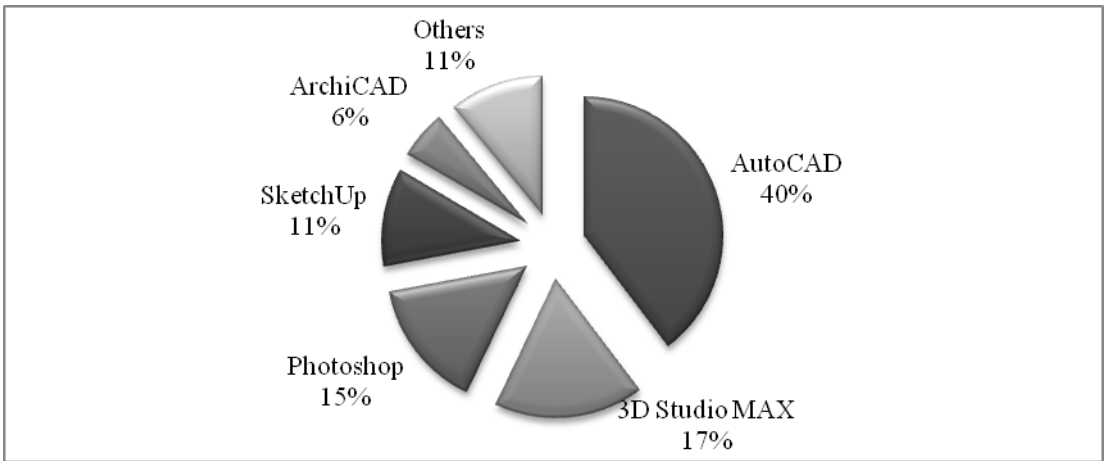

Figure 3.6 Percentage distribution of the use of software packages students utilize

Furthermore, the analysis of most commonly used software are separated into two parts; in the first part the students selected the software from a list that they commonly use, and in the second part the students voluntarily specified the software they utilized frequently in their interior architectural design process. The distribution of these software packages are illustrated in Figure 3.7 and Figure 3.8.

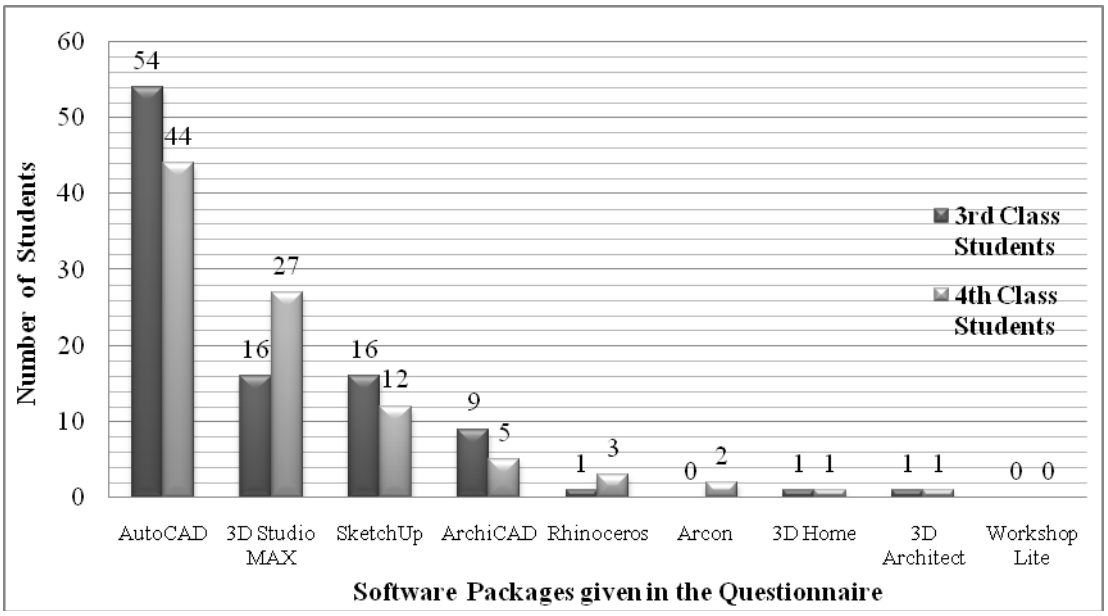

Figure 3.7 Distribution of the use of the given software packages in the questionnaire

It is critical to emphasize that, although Photoshop is not stated in the questionnaire, as it belongs a 2D image processing software family, it is revealed that a considerable amount of the students use Photoshop in their design process after modeling and rendering their project (Figure 3.8). This emphasizes to the assumption that the software they use may not meet all their requirements and they could not reach the desired image they anticipate. Thus, this is an important input for the proposed model.

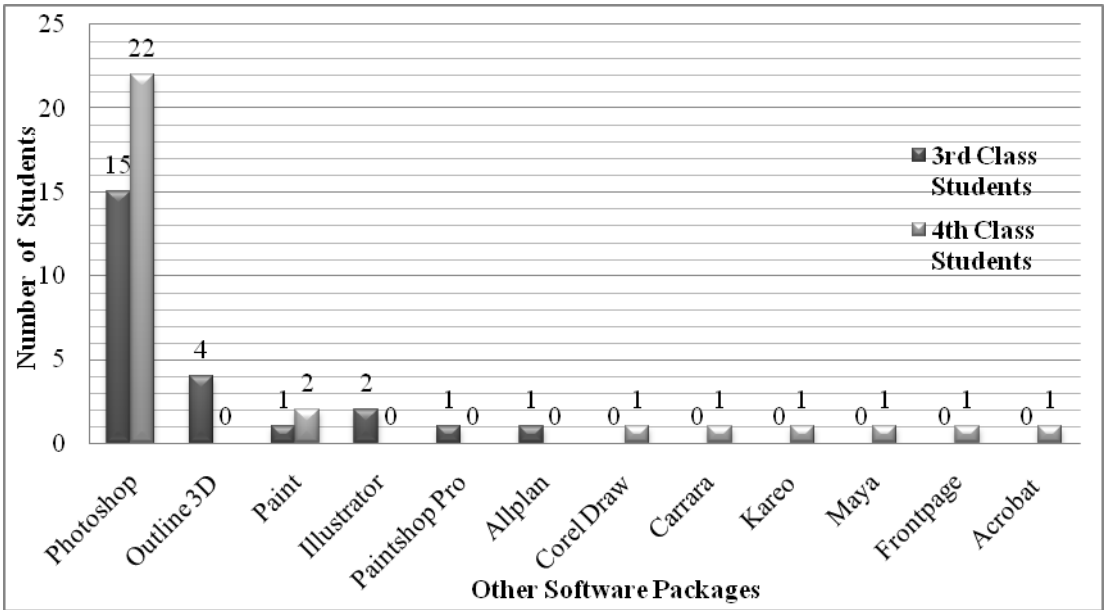

Figure 3.8 Distribution of the use of other written software packages

Next, the software packages utilized in different interior architectural design phases are examined throughout this questionnaire. This examination is basically performed to gather data to see if the software packages employed in each phase are different or not, and to select the most successful software in each phase. The findings are comprehensive and may also used for future work.

A typical architectural project process can be broken into several standard and well defined phases as Kim (1999) stated, such as 'conceptual design and programming', 'schematic design', 'design development', 'constructing documentation' and 'construction supervision'. Parallel to these phases, in this study design phases is resolved into three main phases, as *conceptual design, project development* and *presentation phase*. Although these phases can be increased and more detailed, the grouping is kept as this to be applicable both for students and professionals. The results of the analyses of the questionnaire related to these phases are demonstrated respectively in the following figures.

Conceptual Design Phase

Initially, Figure 3.9 represents the percentage distributions of the software utilized in conceptual design phase. The percentage distribution of Photoshop (37%) is more than any other software package which verifies the importance of 2D design and rendering in conceptual design phase. After Photoshop, AutoCAD comes with 25%. Although AutoCAD limits users by requiring technical and detailed drawing, it is the second mostly preferred software in *conceptual design,* since it provides an easier transition to other phases. Moreover, it can be derived from Figure 3.10 that, even though SketchUp is developed specifically for conceptual design phase, it may only come up as the third commonly used software with 21%.

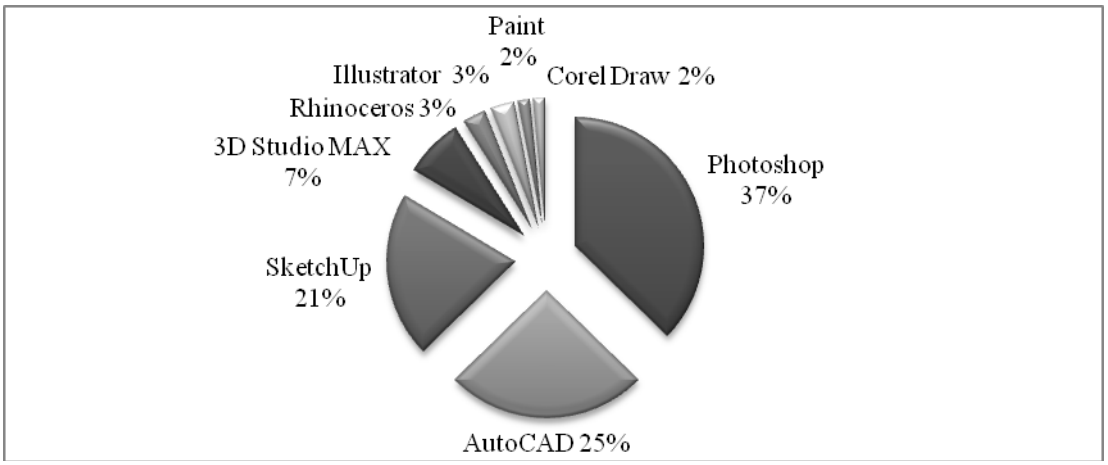

Figure 3.9 Percentage distribution of the use of software packages in *conceptual design phase*

In addition to the analyses in the *conceptual design phase*, those software packages are also examined to find out the most sufficient software packages used by junior and senior students (Figure 3.10).

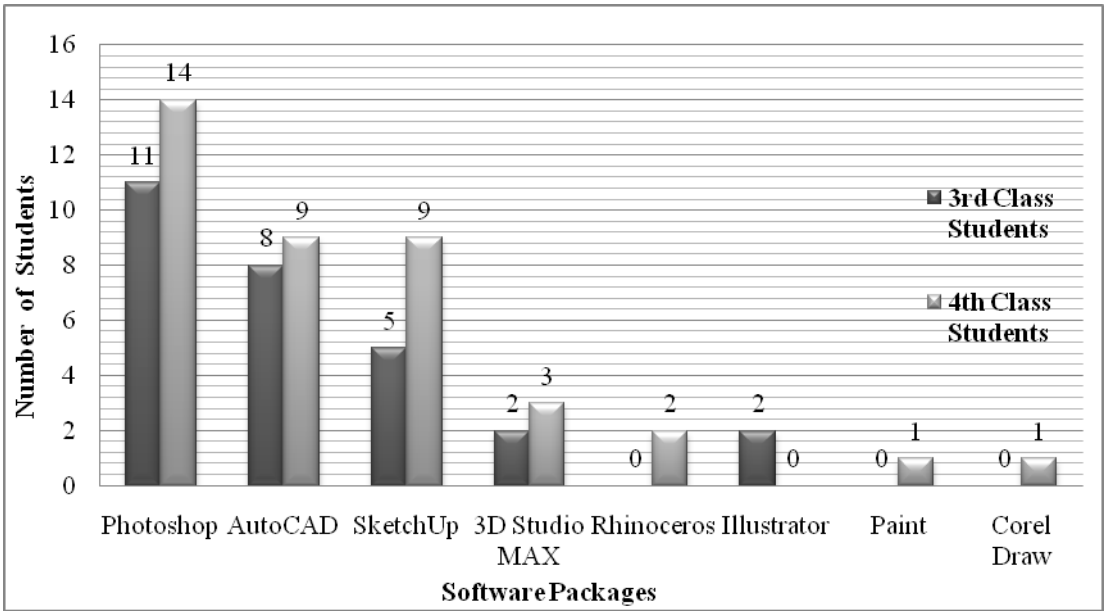

Figure 3.10 Distribution of the use of software packages in *conceptual design phase* according to 3rd and 4th year students

Furthermore, in the *conceptual design phase*, the reasons of sufficiency of CAAD software packages are represented in Table 3.12. These analyses show that the most important factor that affects students to prefer Photoshop is lying in its extensive 2D graphical representation features. Being the best known software (or the one learnt at university) is the most important reason to employ AutoCAD over *conceptual design phase*. Moreover, in Table 3.12, the reasons for the insufficiency of the CAAD software in *conceptual design phase* are given in detail. For instance, the most common reason not to use ArchiCAD in *conceptual design phase* is not to be able to use software easily.

Table 3.12 Reasons for utilizing a specific CAAD software package in *conceptual design phase*

Software Packages	**The Reasons**
Photoshop	2D graphical representation
	Text effects and fonts
	Ease of use
	Support different picture formats
AutoCAD	Best known software
	2D graphical representation
	3D modeling
	Easy transition from sketch to plan
	Ease of use
SketchUp	3D Modeling
	Interoperability between 2D and 3D
	Ease of use
3D Studio Max	Best known software
	Photorealistic image rendering
Rhinoceros	3D modeling
Illustrator	2D graphical representation
Paint	Ease of use

Table 3.13 Reasons for discontent for a specific CAAD software package in *conceptual design phase*

Software Packages	**The Reasons**
Photoshop	Insufficient Use of the Software
	Insufficient in Conceptual Design Phase
	Insufficient 3D Drawing features
AutoCAD	Insufficient Use of the Software
	Too much Detailed and Technical
	Insufficient 2D graphical features
3D Studio MAX	Insufficient Use of the Software
	Insufficient in Conceptual Design Phase
	Insufficient 2D Graphical Representation features
ArchiCAD	Insufficient Use of the Software

Project Development Phase

Secondly, in the p*roject development phase*, as Figure 3.11 shows, AutoCAD is more utilized than other software packages with 72%. While Photoshop and SketchUp lose their popularity in this phase, 3D Studio Max starts to be one of the most commonly used software in *project development phase*.

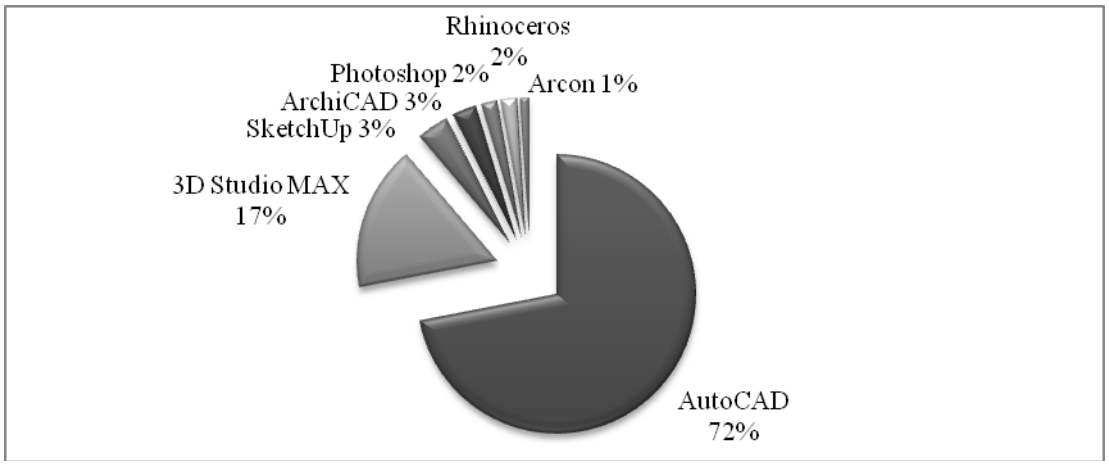

Figure 3.11 Percentage distribution of the use software packages in *project development phase*

Furthermore, the distribution of software packages used by the third and fourth class students in *project development phase* is shown in Figure 3.12.

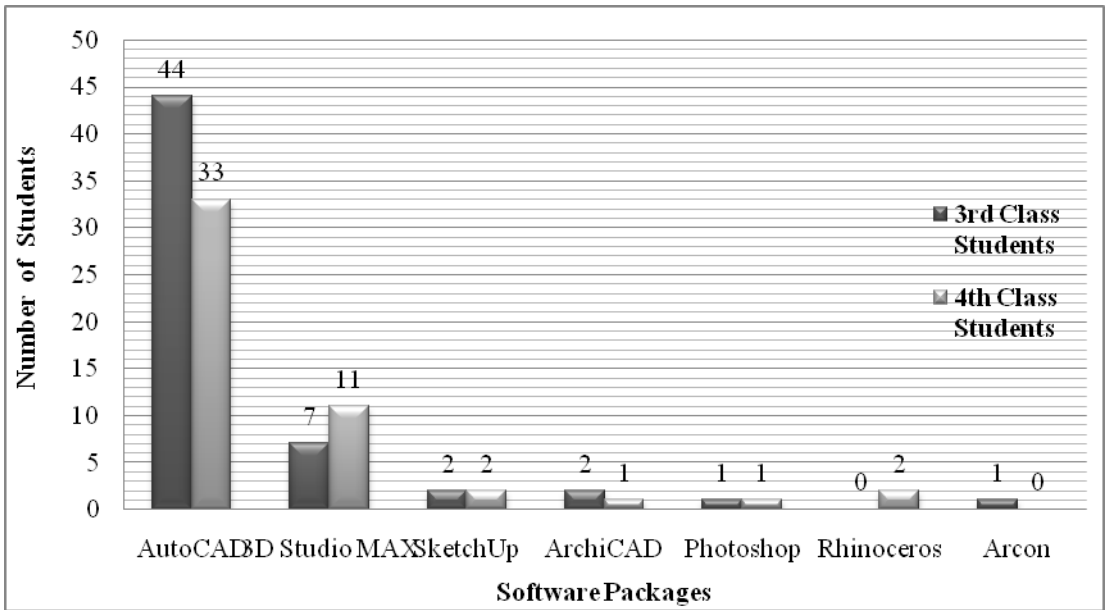

Figure 3.12 Distribution of the use of software packages in *project development phase* according to 3rd year and 4th year students

The analysis of sufficiency of the CAAD software packages show that 'ease of use', '3D modeling' and 'rendering' features are the important criteria that affect the employment of that software in *project development phase* (Table 3.14).

Table 3.14 Reasons for utilizing a specific CAAD software package in *project development phase*

Software Packages	**The Reasons**
AutoCAD	Ease of Use
	3D Modeling and Rendering Features
	Best Known Software
	Provide a Detailed and Technical Drawing
	2D Drawing Features
3D Studio MAX	Ease of Use
	3D Modeling and Rendering Features
	Best Known Software
SketchUp	Ease of use
ArchiCAD	Ease of Use
	3D Modeling and Rendering Features
Rhinoceros	3D Modeling and Rendering Features

The following Table 3.15 summarizes the reasons causing the discontent for software used in interior architectural *project development phase*. Although AutoCAD is the most used software in this phase, the disadvantages include having a long processing time and lacking some features in 3D modeling and rendering. On the other hand, one of the least utilized software, Photoshop is found insufficient for both 3D modeling and rendering and also in providing detailed and technically sound drawings.

Table 3.15 Reasons of discontent for a specific software package in *project development phase*

Software Packages	**The Reasons**
AutoCAD	Long Processing Time
	Insufficient in 3D Modeling and Rendering
	Insufficient
3D Studio MAX	Insufficient in Project Development Phase
	Insufficient use of the software (not known properly, hard to use)
SketchUp	Insufficient in 3D Modeling and Rendering
	Insufficient in Detailed and Technical Drawing (not an architectural software)
	Insufficient
ArchiCAD	Insufficient use of the software (not known properly, hard to use)
Photoshop	Insufficient in 3D Modeling and Rendering
	Insufficient in Project Development Phase
	Insufficient in Detailed and Technical Drawing (not an architectural software)
	Insufficient
Illustrator	Insufficient in 3D Modeling and Rendering

Presentation Phase

Presentation phase is the last phase that is examined during questionnaire analyses. In this phase, since the 2D and 3D drawings and representations are crucial, it is perceived that the software packages possessing extensive 2D and 3D drawing features gain importance. AutoCAD is again the most commonly utilized software with 41%, then 3D Studio Max comes as the second one with 22% and Photoshop comes as third with 20% of the total student votes (Figure 3.13).

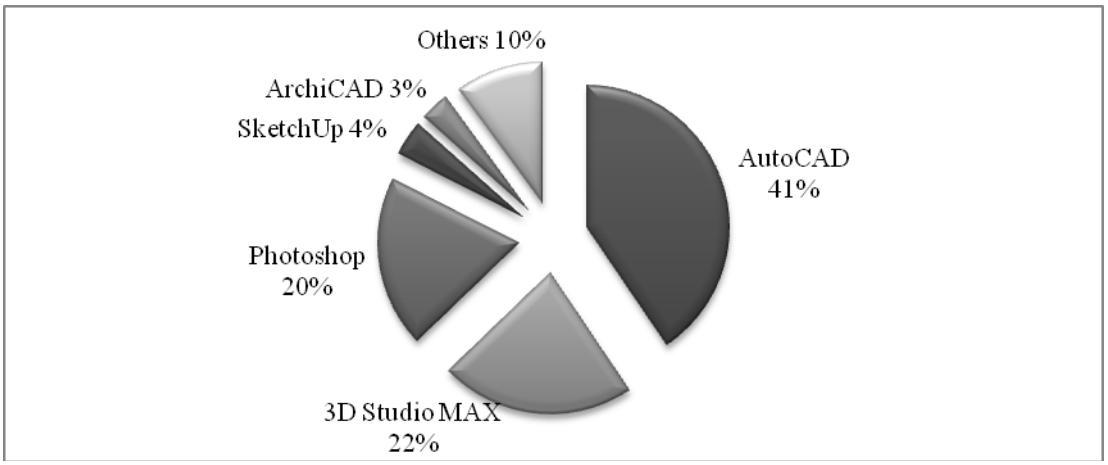

Figure 3.13 Percentage distribution of the use of software packages in *presentation phase*

Also, there is an increase in the number of the software packages used in *presentation phase* as Figure 3.14 denotes. It can be associated with the sufficiency of the new software packages in *presentation phase* than the ones used throughout the design process. As students stated, 'ease of use' again is the most important criteria existing in all of the software packages used in *presentation phase* (Table 3.16).

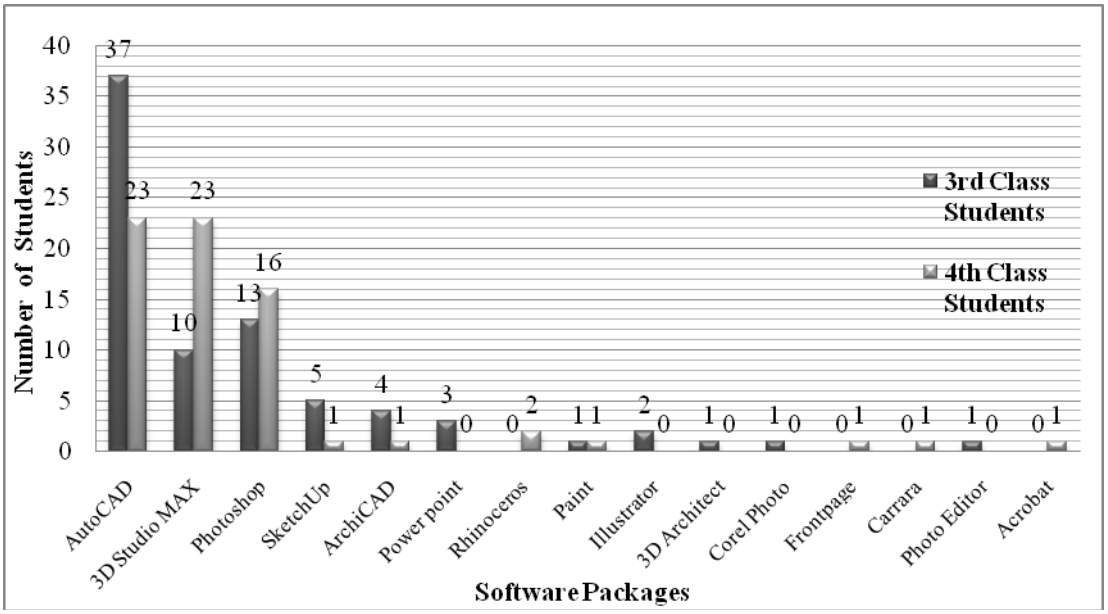

Figure 3.14 Distribution of the use of software packages in *presentation phase* according to 3rd and 4th year students

Table 3.16 Reasons for utilizing a specific CAAD software package in *presentation phase*

Software Packages	**The Reasons**
AutoCAD	Best known software
	Sufficient in Detailed and Technical Drawing
	Ease of use
	Sufficient in 2D Drawing and Presentation
	Sufficient in 3D Modeling and Presentation
	Sufficient in all Phases of the Project Design
	Sufficient in Project Presentation Phase
3D Studio MAX	Ease of use
	Sufficient in 3D Modeling and Presentation
	3D Modeling and Rendering Quality
	Animation Feature
Photoshop	Ease of use
	Sufficient in 2D Drawing and Presentation
	Sufficient in Project Presentation Phase
	Sufficient in Photographic Effects
SketchUp	Ease of use
	Sufficient in 3D Modeling and Presentation
	3D Modeling and Rendering Quality
ArchiCAD	Ease of use
Rhinoceros	3D Modeling and Rendering Quality
Illustrator	Ease of use
Powerpoint	Ease of use

Insufficient 3D modeling and rendering features, and insufficient use of the software by the user due to the lack of a proper knowledge and finding the software hard to use, are the most popular two reasons for not being satisfied with a software package in *presentation phase* (Table 3.17).

Table 3.17 Reasons for discontent for a specific CAAD software package in *presentation phase*

Software Packages	**The Reasons**
AutoCAD	Insufficient in 3D Modeling and Rendering
	Insufficient Use of the Software (not known properly, hard to use)
	Insufficient in Project Presentation Phase
3D Studio MAX	Insufficient Use of the software (not known properly, hard to use)
Photoshop	Insufficient in 3D Modeling and Rendering
	Insufficient Use of the Software (not known properly, hard to use)
	Insufficient in Detailed and Technical Drawing (not an architectural software)
SketchUp	Insufficient in 3D Modeling and Rendering
Paint	Insufficient in 3D Modeling and Rendering
Arcon	Insufficient Use of the Software (not known properly, hard to use)

To conclude, considering the software packages analyzed, AutoCAD can be tagged as the most commonly used software package addressing all interior design phases with all of its advantages and disadvantages.

User Needs

In addition to the analyses made in design phases, to verify the insufficiency of general purpose CAAD software and to reveal the necessity of a new domain specific software package, students are asked three main questions about general purpose insufficiency, domain specific software necessity and need for a new interior architectural domain specific software.

Initially, students are questioned whether they find general purpose CAAD software sufficient or not. Contrary to 'assumption 2' given (chapter 3.2.1.1), 15% of the students and 55% of the students answered as they find general purpose always and often sufficient (Figure 3.15). The distribution of these responses of the third and fourth year student can be seen in Figure 3.16 in detail.

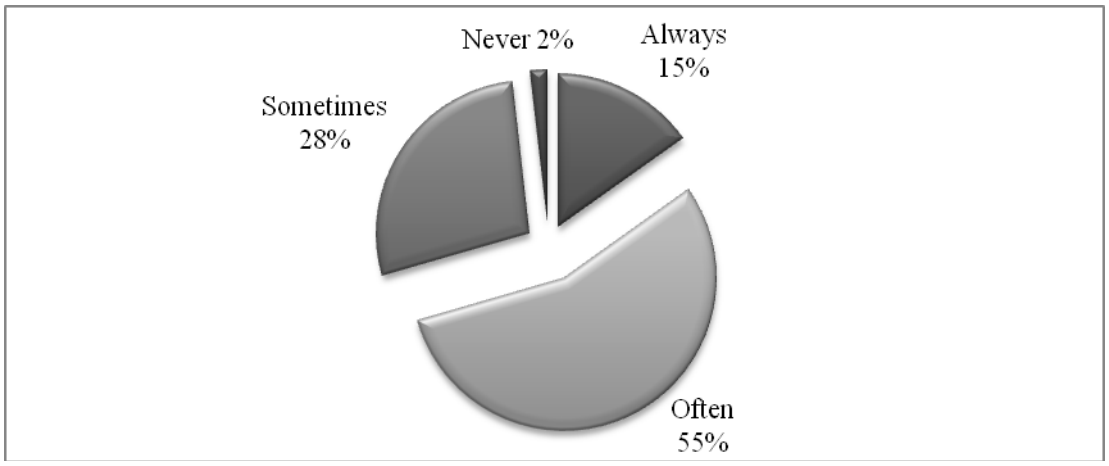

Figure 3.15 Percentage distribution of satisfaction with general purpose CAAD software

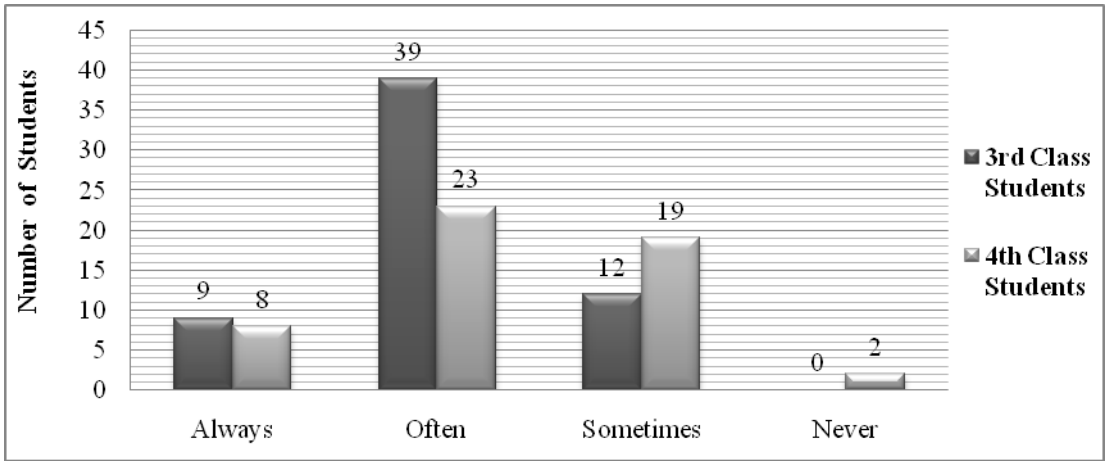

Figure 3.16 Distribution of satisfaction with general purpose CAAD software

Another question in this issue determined the percentage distribution of responses of students to necessity of domain specific CAAD software (Figure 3.17). As predicted in 'assumption 3' (chapter 3.2.1.1), most of the students agree that there is a necessity for a domain specific CAAD software package in interior architecture. In the Figure 3.18 the distribution of the responses of the students are shown.

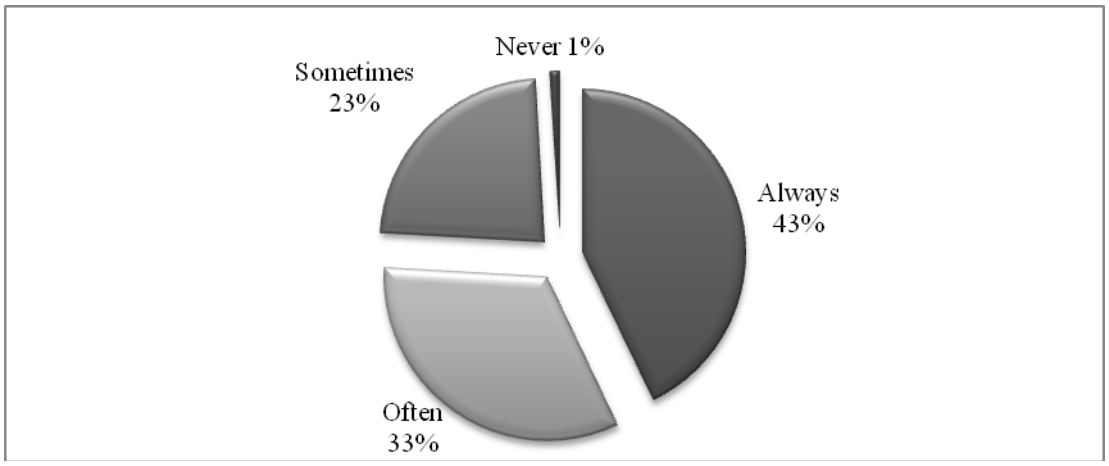

Figure 3.17 Percentage distribution of needing domain specific CAAD software in interior architectural design

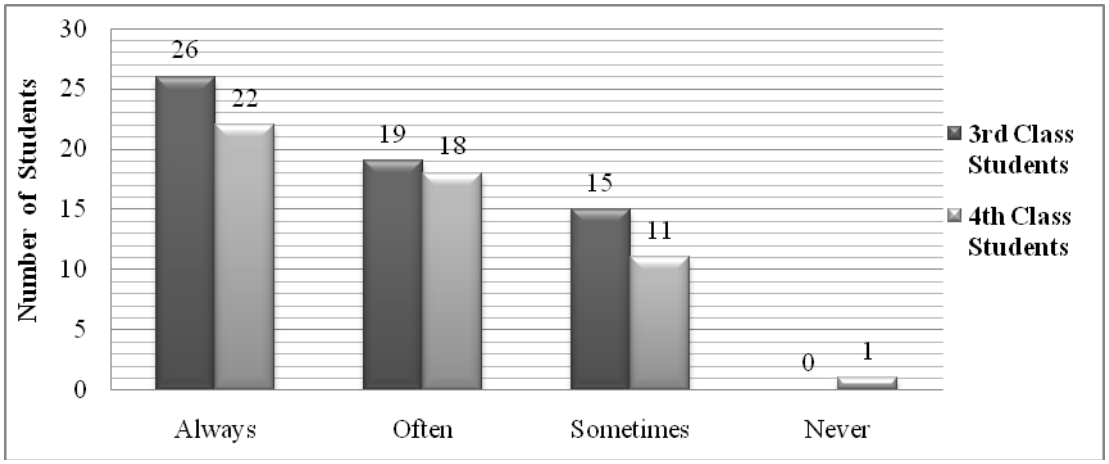

Figure 3.18 Distribution of needing domain specific CAAD software in interior architectural design

After confirming the necessity for domain specific software, the last question inquiries whether the students have a tendency to use such a software package during their interior architectural design. As Figures 3.19 and 3.20 indicate that there is a remarkable tendency in using such a new domain specific software.

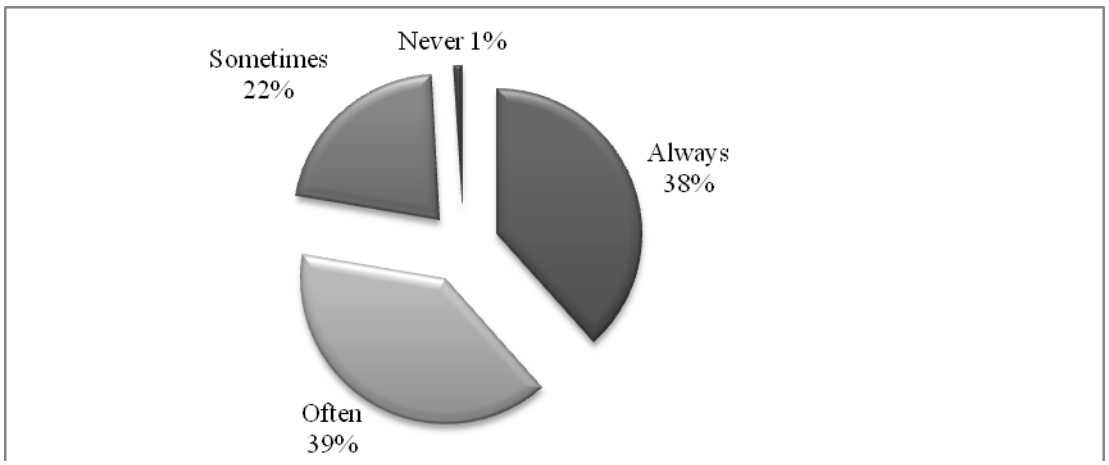

Figure 3.19 Percentage distribution of students' tendency in using a new domain specific interior architectural software

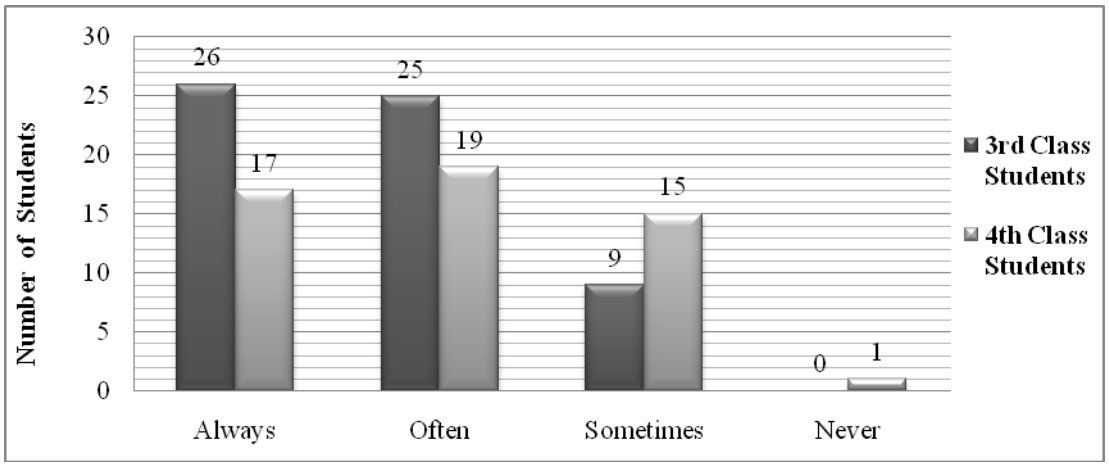

Figure 3.20 Distribution of students' tendency in using a new domain specific interior architectural software

This part of the empirical data focuses on the user needs towards the 12th and the 13th questions stated in the questionnaire (Appendix A.1). In the 12th question, nine items are extracted, bearing in mind the CAAD objects and operations defined by (Szalapaj, 2001), in which students chose five most useful ones by giving credits to each of them (Figure 3.21). Moreover, Figure 3.22 represents the distribution of rates of students in these criterion stated. These analyses show that the top five items respectively are;

- Transition from 2D into 3D
- Photorealistic rendering
- Easy transformation of 3D objects
- A shorter processing time
- Ease of learning

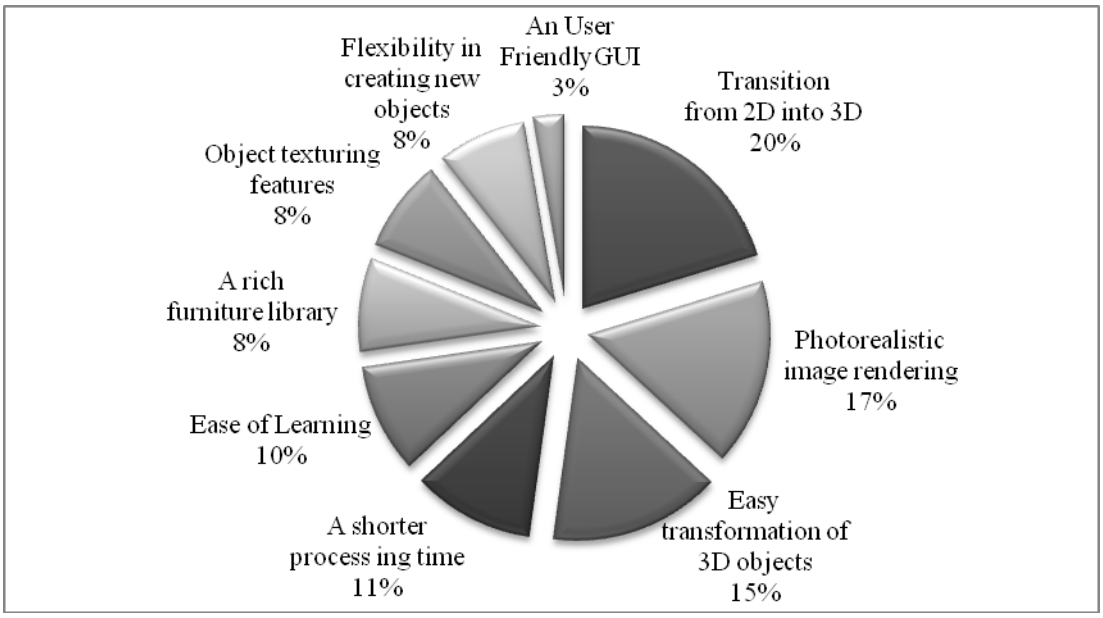

Figure 3.21 Percentage distribution of preferences for using a specific CAAD software

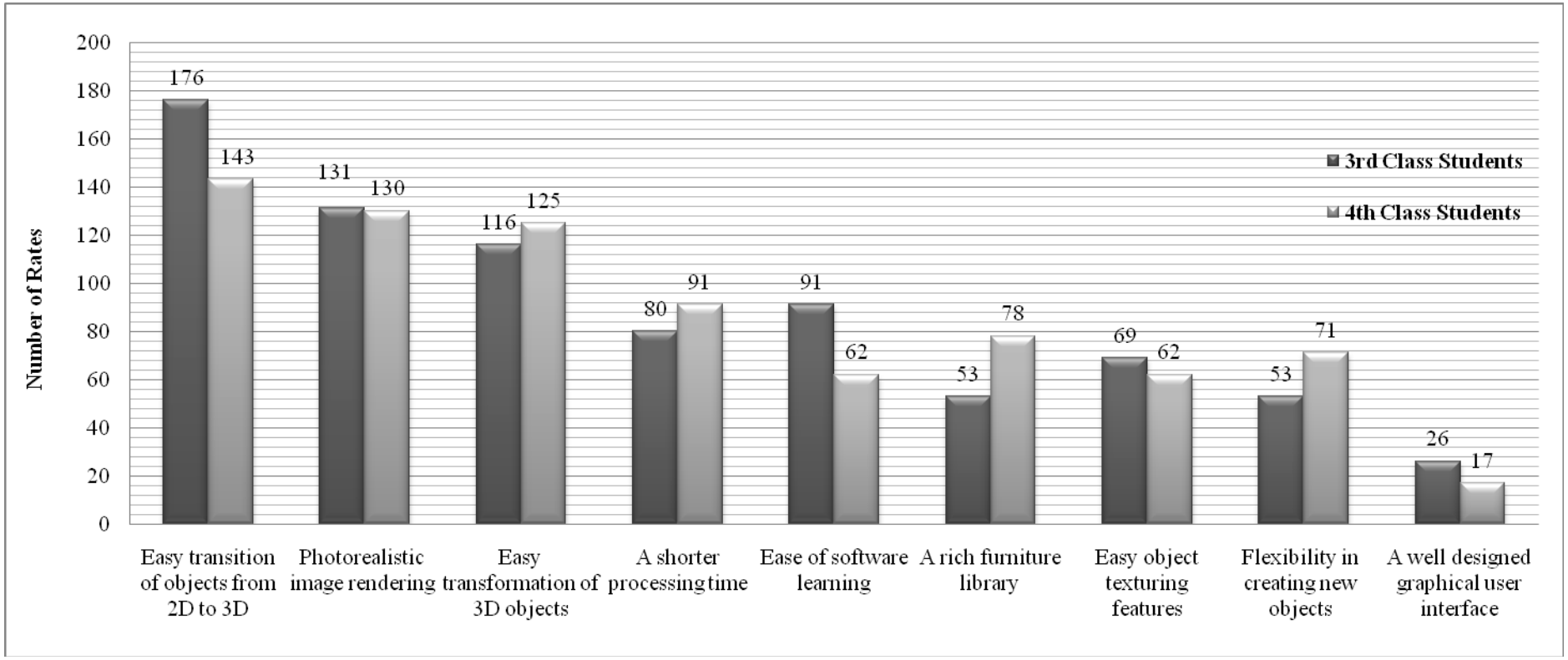

Figure 3.22 Distribution of preferences for using a specific CAAD software according to 3rd and 4th year students

The 13th question is an open ended, free text one in which students can write down their software needs for a newly developed interior architectural software package. These needs are figured out and classified into two; software features and software quality attributes. Software features contain 'drawing', 'transformation', 'view', 'rendering' and 'other features', such as; 'collaboration' and 'interoperability', which affects how the software system functions. On the other hand, software quality attributes involve 'ease of use', 'reliability', 'efficiency', 'flexibility' and 'other attributes', which affects the quality of the software.

Table 3.18 embodies the analysis of software features. These features are also categorized under main headings. The most extensive list includes 'rendering' features, in which students would like to have nearly all of the features related to 'material', 'lighting' and 'rendering', the features which a software package can include in order to reach the photorealistic image they desire. The important point here is, although the students wish to have all of the features meeting interior architectural domain requirements; they also want the new software to resemble the general purpose software packages they use, like AutoCAD and 3D Studio Max. Thus, it is highly important to consider this situation while developing a new software package for interior architecture.

Table 3.18 Students' needs in terms of software features

Feature List	**User Needs**
Drawing	Provide an extensive Furniture Library
	Provide Architectural Elements (like stairs, lifts)
	Provide Landscape Elements Library
	Provide proper 2D Drawing Tools
	Provide 3D Modeling Features and Tools
Transformation	Provide extensive 3D Geometrical Transformations
	Provide efficient Transition between 2D and 3D
View	Provide Photorealistic View
	Provide Cameras with Video and Animation Features
	Provide 3D Views and Perspectives
Rendering	Provide an extensive Material, Texture and Color Library
	Provide Photorealistic Materials
	Provide Material Editing Features
	Provide various Lighting Elements
	Provide extensive Lighting Features
	Provide Global Rendering (Photorealistic Lighting and Rendering)
	Provide extensive Rendering Features
Other Features	Provide resemblance to AutoCAD in 2D Drawing Features
	Provide resemblance to 3D Studio MAX in 3D Modeling Features
	Provide Layering Feature
	Provide a Command Line and Shortcuts
	Provide User Coordinate Systems (UCS)

The following Table 3.19 concludes the student needs about software quality attributes. The quality attributes unveil the hidden factors behind the software features that a software package must have. The users wish to have an easier to use, more reliable, more efficient and a more flexible software package for their design process. Providing interoperability and collaboration during the design

process, resembling to the hand drawing and being interesting software are also factors affecting the software quality as well. The proposed model in the following chapter also includes these attributes.

Table 3.19 Students' needs in terms of software quality attributes

Quality Attributes	**User Needs**
Ease of Use	Provide easy 3D Object Modeling
	Provide easy Interoperability between 2D and 3D
	Provide easy 3D Object Transformation
	Provide easy 3D Object View (Perspectives)
	Provide easy Material Editing and Attaching
	Provide easy Light Editing
	Provide easy Object Rendering
	Provide easy Software Use (Commands)
	Provide easy Interface Use and Perception
	Provide easy Software Learning
Reliability	Provide Reliability in 2D Drawing
	Provide Reliability in 3D Modeling
	Provide Reliability of Software (Recovering Mistakes)
Efficiency	Provide a shorter Processing Time (Quality in Result)
	Provide a shorter Rendering Time
Flexibility	Provide Flexibility in creating New Objects (instead of object library)
	Provide Flexibility in allowing users to Draw Every Shape
	Provide Flexibility of Software
Other Attributes	Provide Interoperability between different Software Packages
	Provide Collaboration in a Project
	Provide Resemblance to Hand Drawing
	Provide an Interesting Software

Among all of the features and attributes defined, the most important criteria is ‘ease of use’ with 32% of rated by students (Figure 3.23). Then ‘rendering’ feature follows with 20% and ‘drawing’ feature with 10% of the total ratings. Also, the distribution of these rates between the third and fourth year students is shown in Figure 3.24.

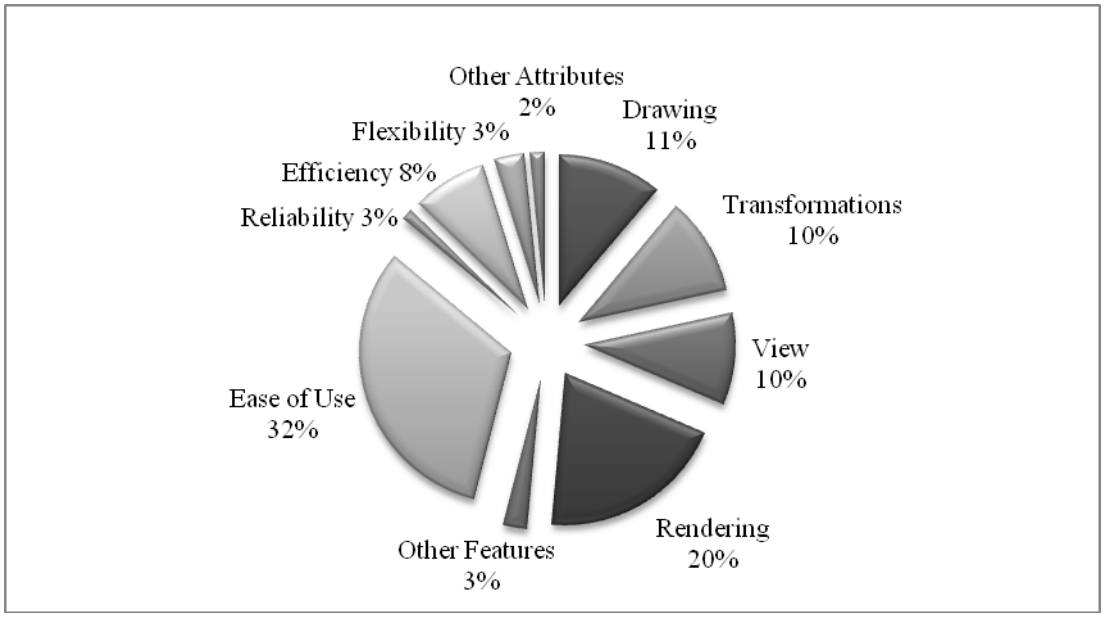

Figure 3.23 Percentage distribution of students’ needs in software features and software quality attributes

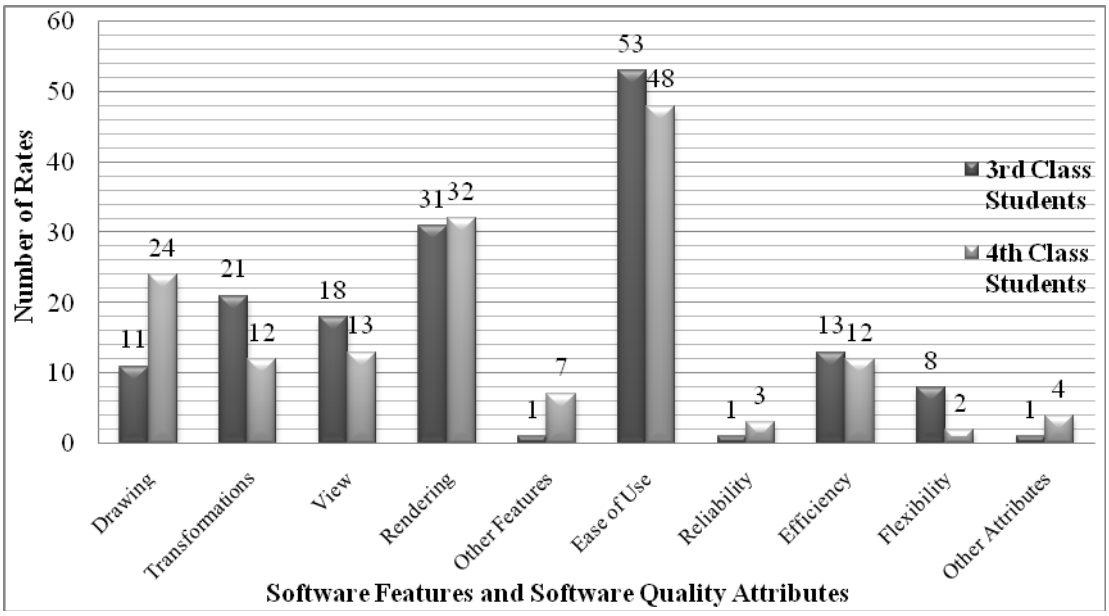

Figure 3.24 Distribution of students' needs in software features and software quality attributes

To sum up, in this part of the empirical data gathered from questionnaire with the students, the following points are highlighted;

- AutoCAD is noted as the most commonly used software in interior architectural education.
- The software packages used in c*onceptual, project development and presentation phases* of the design education are discovered to differ according to the phase.
- In *conceptual phase* students prefer Photoshop, due to its 2D graphical representation, text effects and fonts.
- In *project development phase*, students utilize AutoCAD because of its detailed and technical drawings, and its ease of use.
- In *presentation phase*, similarly, AutoCAD is the most preferred software used by students due to its general purpose structure and ease of use.

- Although students acknowledged that general purpose software packages currently they use are adequate, they also underline the necessity for a domain specific software in interior architecture.
- The students' needs for a newly developed domain specific software package are 'transition from 2D to 3D' and 'photorealistic image rendering'.

3.2.2 Analysis of Professionals' Preferences

The analysis of the professionals' preferences sums up the information related to professionals' assumptions, interviews and sample groups, and the results of findings from interview analysis.

3.2.2.1 Assumptions

Assumptions about the professionals cover the following issues;

1. General purpose CAAD software is not sufficient for interior architectural practice.
2. Interior architectural professionals use software that are developed specifically for their company or software that are developed by adding plug-ins to general purpose software.
3. Interior architectural professionals need domain specific CAAD software which supports detailed interior architectural requirements (color, lighting, material, furniture, etc.).

3.2.2.2 Interview

An interview (Appendix A.2) was performed depending on the assumptions stated in order to gather information about;

- Professionals' background information about CAAD software packages used,
- The software packages used in interior architectural design process among professionals,
- The distribution of use of software packages in *conceptual, project development* and *presentation phases* and the reasons to chose or not to chose these packages in that specific phase,
- The insufficiency of general purpose software throughout interior architectural design process and the reasons,
- The necessity of domain specific software during interior architectural design and the reasons,
- The need for a new domain specific software in interior architecture,
- The user needs for the new domain specific software.

3.2.2.3 Sample Groups

Sample groups of the interview include 20 professionals. These professionals are randomly selected from different companies specialized in different branches of interior architecture, such as; kitchen, bathroom, bedroom and companies specialized especially in interior architectural design and decoration. Figure 3.25 represents, 16

of interviewees are specialized in kitchen, bathroom and bedroom design and 4 of them are specialized in interior architectural design and decoration. Among the 20 interviewees, 11 of them are interior architects, 5 of them are architects and 4 of them are non-designers (sale representative, etc.), and 60% of the interviewees are female and the rest 40% are male. All of the interviewees employ software during their design process. They have 6.75 years of average computer use regardless of their qualifications.

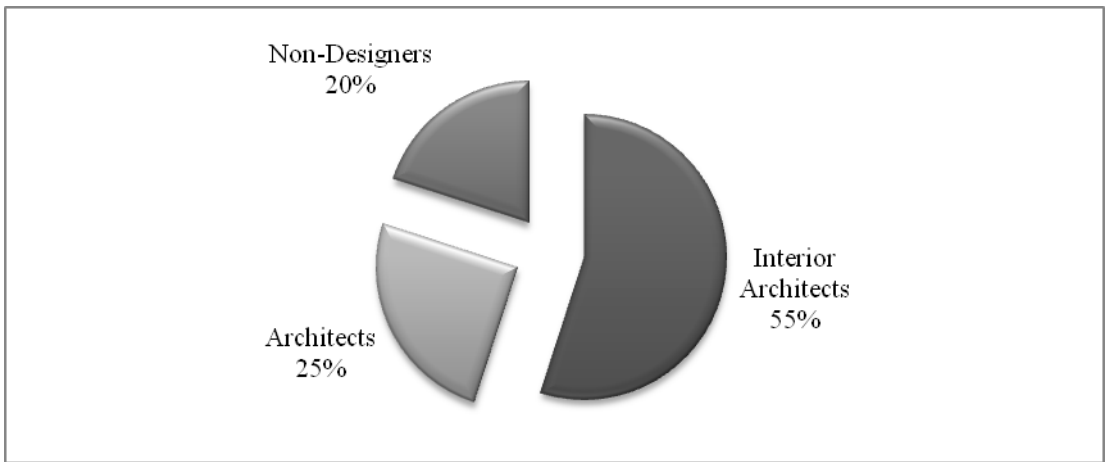

Figure 3.25 Percentage distribution of qualifications of professionals

3.2.2.4 Findings

The data gathered from the analyses of the interviews (Appendix A.2) from 20 interior architectural professionals are presented in this part. The interview involves similar questions like the questionnaire with the students. As the questions are structured around the same framework, the data gathered is presented in the same sequence as in the questionnaire.

The analyzed data in the interview are composed of two main parts. In the first part, most commonly used software packages in interior architectural practice and in interior architectural design process are analyzed. Then, in the second part, the user needs are obtained through questionnaire and are classified.

Initially, the first part covers the most commonly used software in practice and software packages utilized in the design phases based on the categorization in the previous chapter. In addition, the reasons of using these software packages are examined.

The overall distribution of software packages in interior architectural practice is illustrated in Figure 3.26. Although recently in the market various different software packages emerged, contrary to the 'assumption 2' (chapter 3.2.2.1), AutoCAD is still the most preferred software package. The foremost reason of the emergence of these new software is the lack of domain specific software to interior architecture. Companies, who are trying to find appropriate software to use, simply utilize a software package that is specifically developed for their own company, while leading to a chaos in interior architectural practice. The 'others' categorized in Figure 3.26 include the examples of these software packages, such as; 20*20[23], Isigraph, IntelliCAD[24], Infowood[25], TepeCAD, Erkem, PenCAD, Microstation v8[26] and Carad, which the details are given in Appendix B.1.

[23] 20-20 is a registered trademark of 20-20 Technologies.
[24] IntelliCAD is a registered trademark of IntelliCAD.
[25] Infowood is a registered trademark of Design Effective.
[26] Microstation is a registered trademark of Bentley.

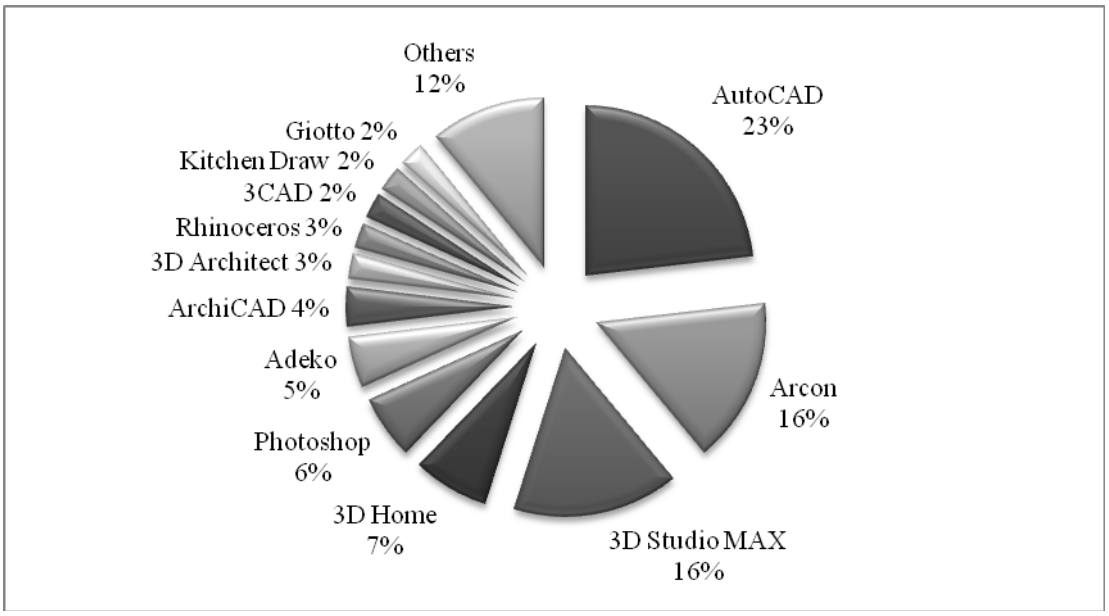

Figure 3.26 Percentage distribution of the use of software packages professionals utilize

Moreover, Figure 3.27 shows a more detailed picture in the general usage of software packages. The distribution of rates of professionals revealed that among the software packages given in the interview, AutoCAD is used by 19 professionals out of 20.

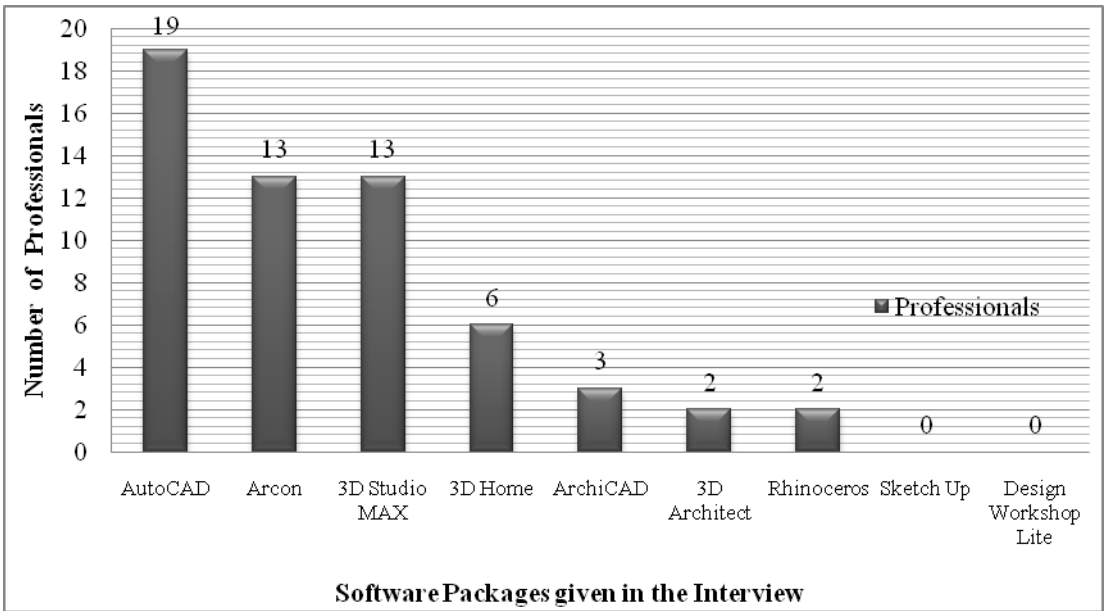

Figure 3.27 Distribution of the use of the given software packages in the interview

The chaotic situation of the software packages can be simply extracted from Figure 3.28. The voluntarily specified software by the professionals gives important clues about the software specially utilized by different companies. For instance, while Arcon is a software package used by Armadi Art company for bathroom design; Raydolap, which is a company specialized in bedroom design, utilize Arcon again but with a different predetermined object library to its own.

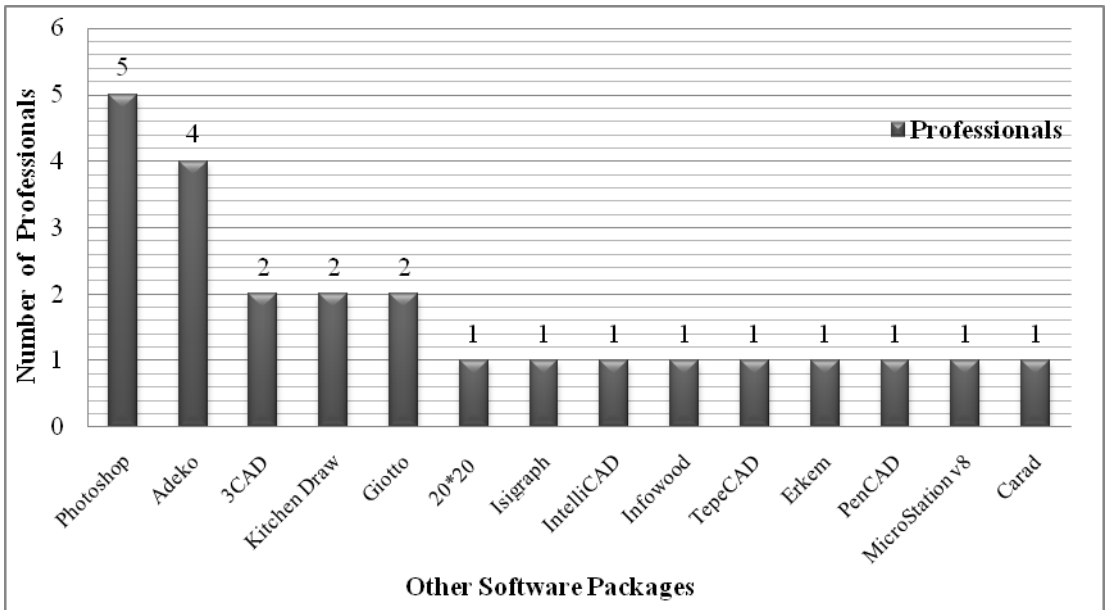

Figure 3.28 Distribution of the use of other software packages

Conceptual Design

In the *conceptual design phase*, most of the professionals prefer to use respectively AutoCAD, Arcon and Adeko[27] (Figure 3.29). As Figure 3.30 represents, the number of professionals is less than the previous analysis. There is a significant decrease in

[27] Adeko is a registered trademark of Adeko Group.

the number of professionals using a software package during *conceptual design phase*. 6 out of 20 professionals do not prefer to use computers in the *conceptual design phase* in order to speed up their design process. Moreover, these professionals often state that using computers will decrease their creativity.

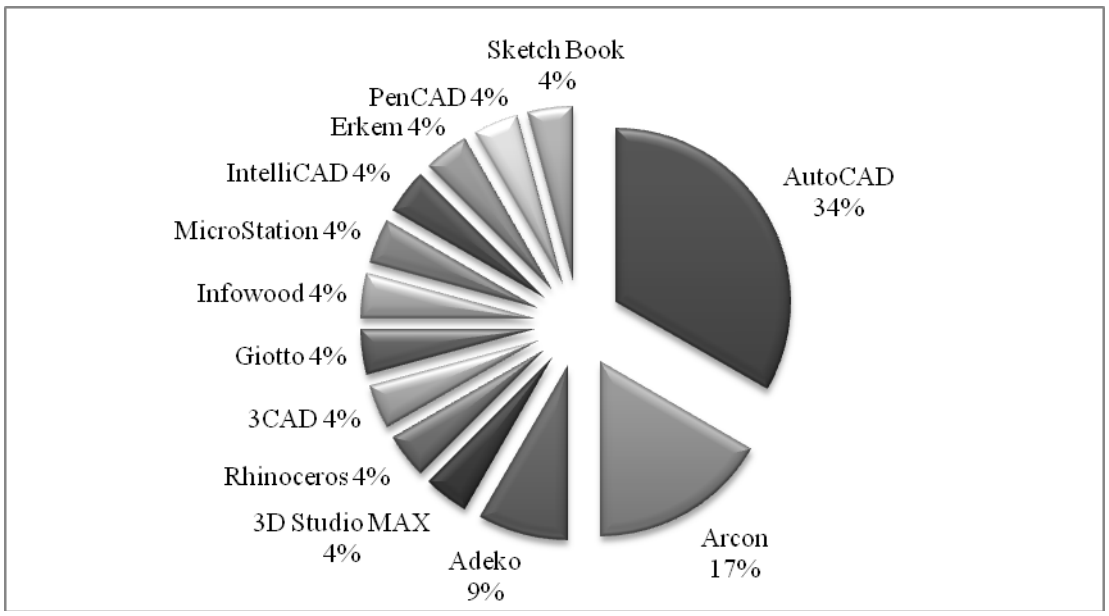

Figure 3.29 Percentage distribution of the use of software packages in *conceptual design phase*

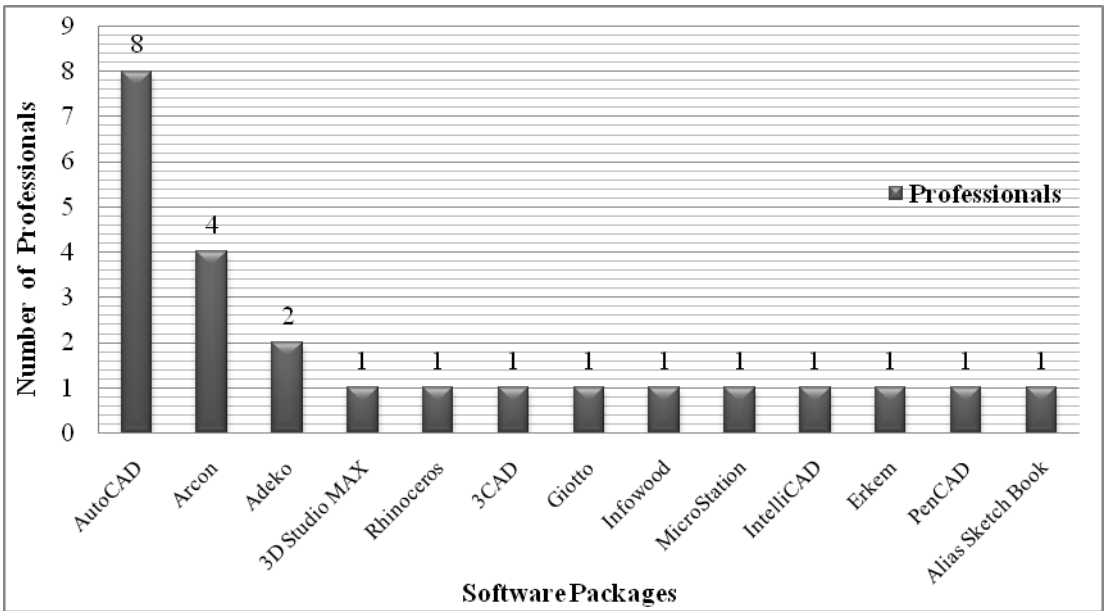

Figure 3.30 Distribution of the use of software packages in *conceptual design phase* according to professionals

Following Tables 3.20 and 3.21 represent the analysis of the reasons of sufficiency and insufficiency of the CAAD software which professionals benefit in the *conceptual phase*. Although the strongest 2D drawing features increase the use of AutoCAD in this phase, being too much detailed and technically complex affect its usage negatively.

Table 3.20 Reasons for utilizing a specific CAAD software package in *conceptual design phase*

Software Packages	**The Reasons**
AutoCAD	2D Graphical Representation
	Flexible and sufficient in 2D Drawing
Arcon	Extensive Texture and Color Library
	Ease of use
Rhinoceros	Ease of use
3CAD	Based on ready-made Object Library of the Company

Table 3.21 Reasons for discontent for a specific CAAD software package in *conceptual design phase*

Software Packages	**The Reasons**
AutoCAD	Too much Detailed and Technical
Arcon	Based on ready-made Object Library of the Company (not Flexible)

Project Development Phase

Project development phase is a more crucial step for the professionals than for the students, since the probability of a project to be realized in professional practice is more than in the educational arena. As Figure 3.31 represents, the professionals verify these statements and they mostly prefer AutoCAD in the *project development phase.* Figure 3.32 shows the distribution of software packages professionals operates in this phase.

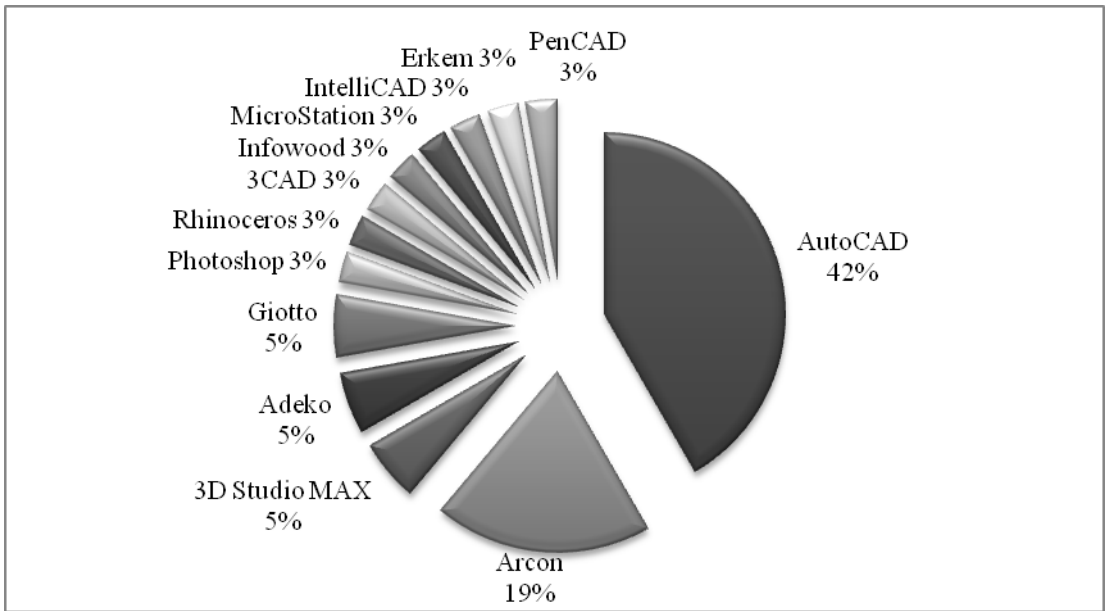

Figure 3.31 Percentage distribution of the use of software packages in *project development phase*

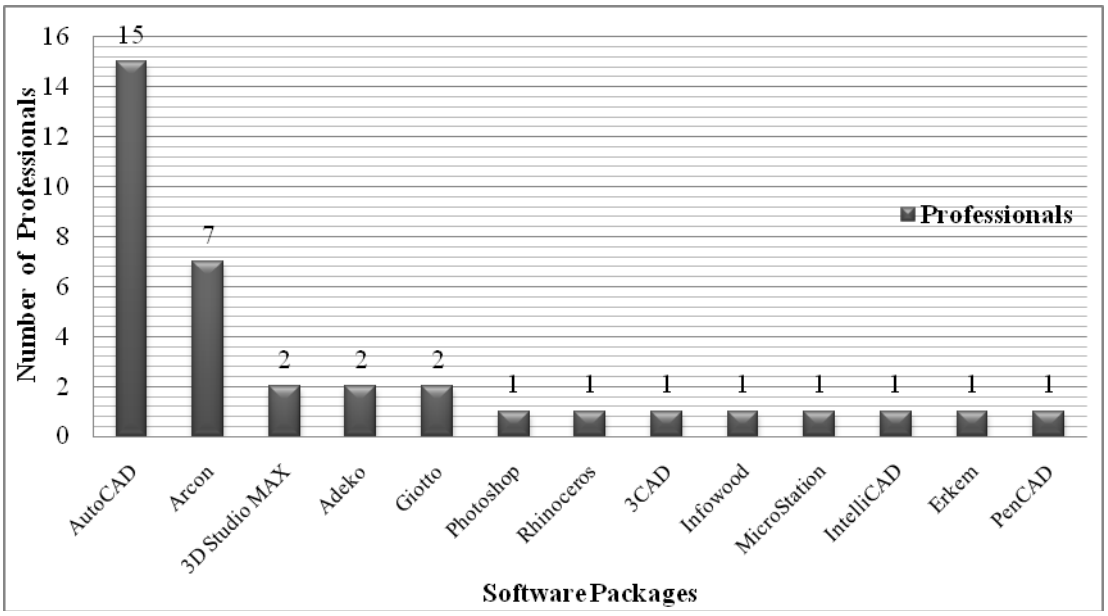

Figure 3.32 Distribution of the use of software packages in *project development phase* according to professionals

Here again, the reasons for utilizing a specific CAAD software *project development phase* is analyzed in Table 3.22. The most important criteria to utilize AutoCAD in this phase are stated as its 'ease of use' and its providing 'detailed and technical drawings' for production or construction.

Table 3.22 Reasons for utilizing a specific CAAD software package in *project development phase*

Software Packages	**The Reasons**
AutoCAD	Ease of Use
	Provide a Detailed and Technical Drawing
	Provide Precise Drawings for Production
	Extensive 2D Drawing Features
	Provides easy Transition to other Design Phases
	An International Software Package
Arcon	3D Modeling and Rendering Features
	Shorter Processing Time
	Cost Estimation Feature
	Extensive Texture and Color Library
3D Studio MAX	3D Modeling and Rendering Features
	Photorealistic Images
3CAD	Best Known Software

Moreover, Table 3.23 summarizes the reasons for insufficiency of the specified software packages. AutoCAD's lack in 'cost estimation' feature, Arcon's 'library' based on the ready made objects of their company, 3D Studio Max's 'insufficiency in providing a proper scale for the drawings' and Photoshop's 'insufficiency in providing detailed and technical drawing' can be counted among the disadvantages of these software.

Table 3.23 Reasons for discontent for a specific software package in *project development phase*

Software Packages	**The Reasons**
AutoCAD	Insufficient in 3D Modeling and Rendering
	Cost Estimation Feature is lacking
Arcon	Based on ready-made Object Library of the Company
3D Studio MAX	Insufficient in providing a proper Scale of the Drawing
Photoshop	Insufficient in providing Detailed and Technical Drawing (only used in 2D image Processing)

Presentation Phase

In the last phase of design process analyzed, it is observed that AutoCAD and Arcon take 21% of the pie and are the most widespread software packages (Figure 3.33). Also, in this phase professionals employ Microsoft Office software, like Excel, Word, Powerpoint and Media Player, by which they calculate the cost of the project and prepare the proposal for the project and its presentation. Finally, Figure 3.34 gives details about the distribution of a number of professionals utilizing these software.

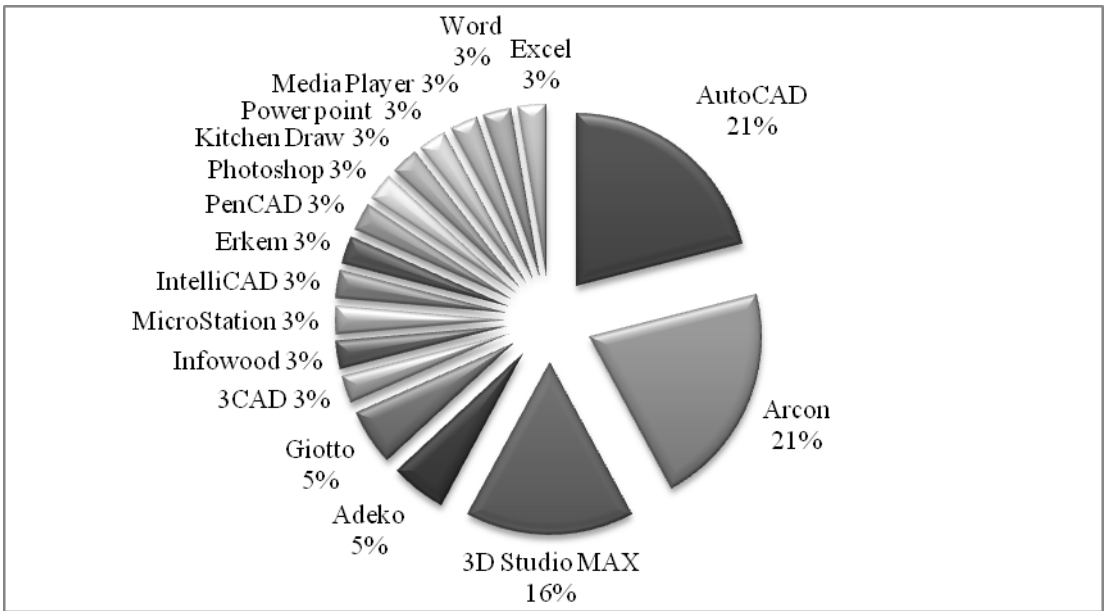

Figure 3.33 Percentage distribution of the use of software packages in *presentation phase*

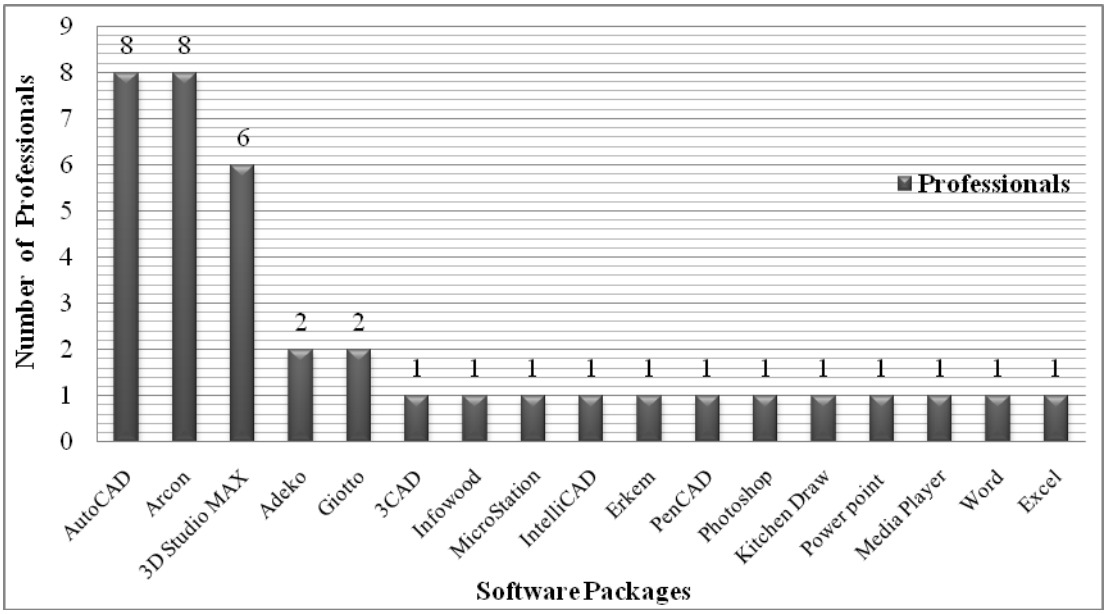

Figure 3.34 Distribution of the use of software packages in the *presentation phase* according to professionals

After obtaining information about the software packages, in Table 3.24, it is stated that collaboration is one of the most important aspects of Arcon. 'Collaboration' within company is significant in the effectiveness of the work process. Also, 'providing a shorter processing time' is another important aspect when the interior architect prepares or modifies the project together with the customer. 2D drawings and 3D models may be modified according to customer needs over and over in a short time. Shortening the time spent for this procedure is a big gain by professionals.

Table 3.24 Reasons for utilizing a specific CAAD software package in *presentation phase*

Software Packages	**The Reasons**
AutoCAD	Shorter Processing Time
	Sufficient in 3D Modeling and Presentation
Arcon	Shorter Processing Time
	Sufficient in 3D Modeling and Presentation
	Provide Photorealistic Images
	Provide Collaboration within the Company
	Ease of use
3D Studio MAX	3D Modeling and Rendering Quality
	Provide Photorealistic Images
	Sufficient in 3D Modeling and Rendering
Giotto	Sufficient in 3D Modeling and Presentation
	Provide Photorealistic Images
	3D Modeling and Rendering Quality
3CAD	Sufficient in 3D Modeling and Presentation
Photoshop	Sufficient in Image Processing
Kitchen Draw	Shorter Processing Time
	Based on ready-made Kitchen and Bathroom Object Library of the Company
Powerpoint	Sufficient in Project Presentation Phase

Table 3.25 emphasizes the insufficient factors affecting the utilization of the specified software in *presentation phase*. For instance, the lacking features in Infowood, such as its insufficiency in 3D modeling and rendering, and insufficiency in flexibility resulted in its limited usage in presentation phase.

Table 3.25 Reasons for discontent of a specific CAAD software package in *presentation phase*

Software Packages	**The Reasons**
AutoCAD	Insufficient in 3D Modeling and Rendering Features
	Insufficient in Cost Estimation
	Too much Technical Drawings (Customers have difficulty in understanding the Drawings)
3D Studio MAX	Long Processing Time
Infowood	Insufficient in 3D Modeling and Rendering (especially Lighting)
	Insufficient in creating Different Forms and Shapes (not Flexible)

User Needs

As in the previous analyses in the questionnaire, the following tables and figures gives detailed information about the insufficiency of general purpose software, necessity of domain specific software and needs of the professionals for new domain specific CAAD software.

Initially, in Figure 3.35, contrary to the 'assumption 1' (chapter 3.2.2.1), it is observed that more than half of the professionals find general purpose CAAD software adequate for interior architectural purposes as students. Figure 3.36

illustrates the distributions of responses of professionals in finding general purpose CAAD software sufficient for interior architectural design.

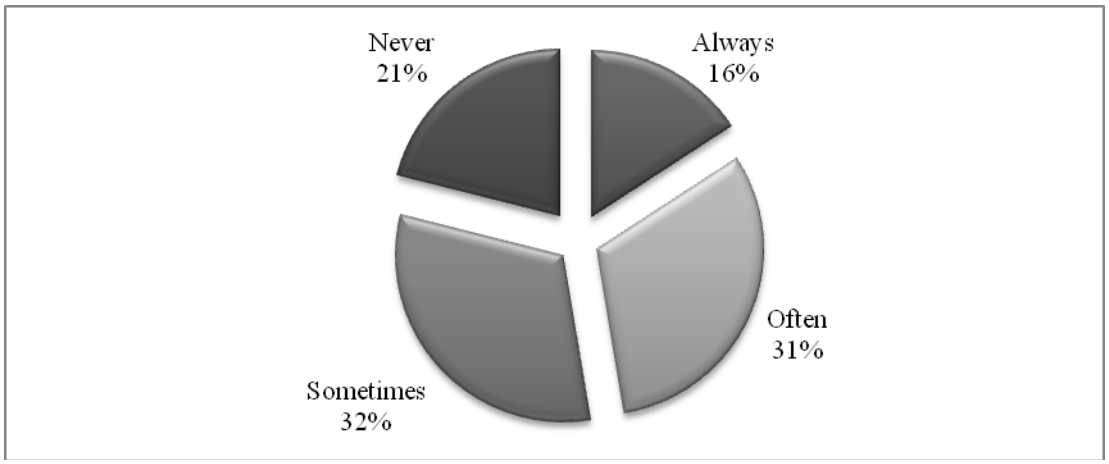

Figure 3.35 Percentage distribution of satisfaction with general purpose CAAD software

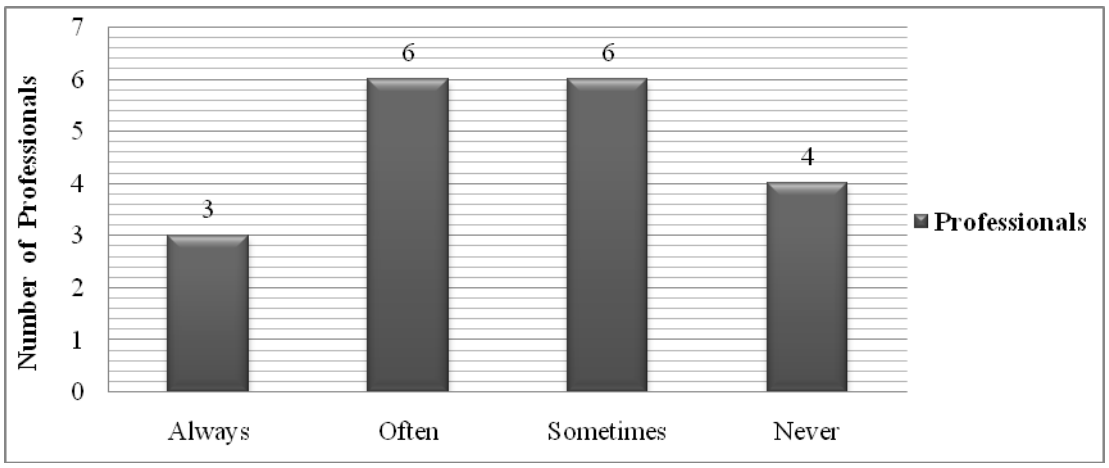

Figure 3.36 Distribution of satisfaction with general purpose CAAD software

Moreover, unlike students, professionals are questioned about the reasons why they find general purpose CAAD software insufficient in interior architectural design (Figure 3.37). The reasons clearly show that limitations of the software packages in interior architectural design and lack of interior architectural details in general purpose software alienate professionals from these software.

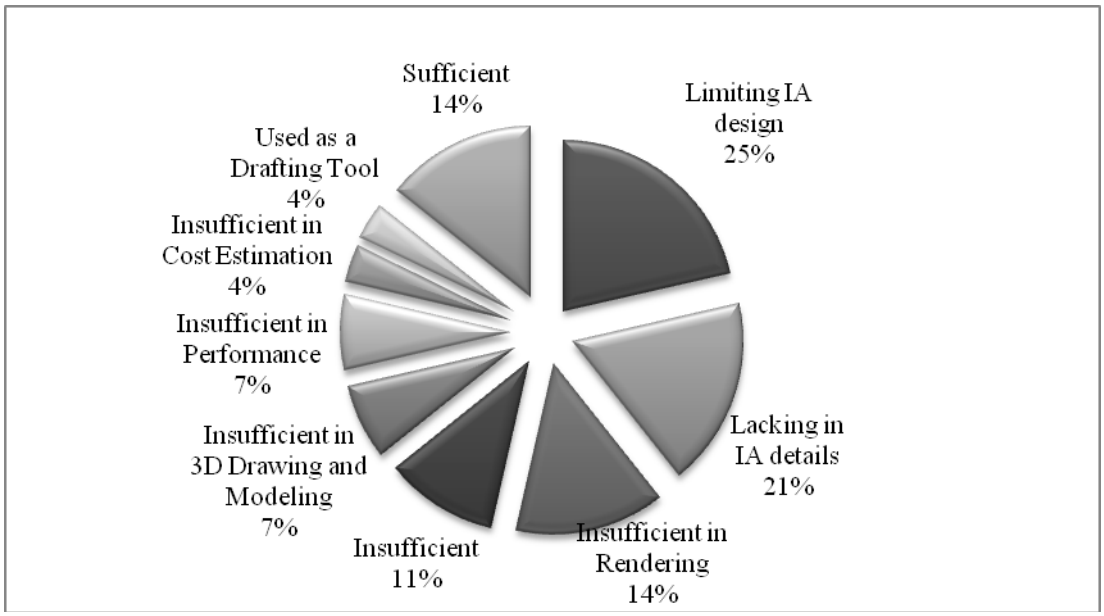

Figure 3.37 Percentage distribution of criteria related to dissatisfaction of general purpose CAAD software

The necessity of the domain specific software is also examined during the interview analysis (Figure 3.38). The outstanding results show that 70% of the professionals approved that there is a necessity for a domain specific software package in interior architectural practice, as stated in 'assumption 3' (chapter 3.2.2.1). Figure 3.39 specifies the numerical distribution of this necessity.

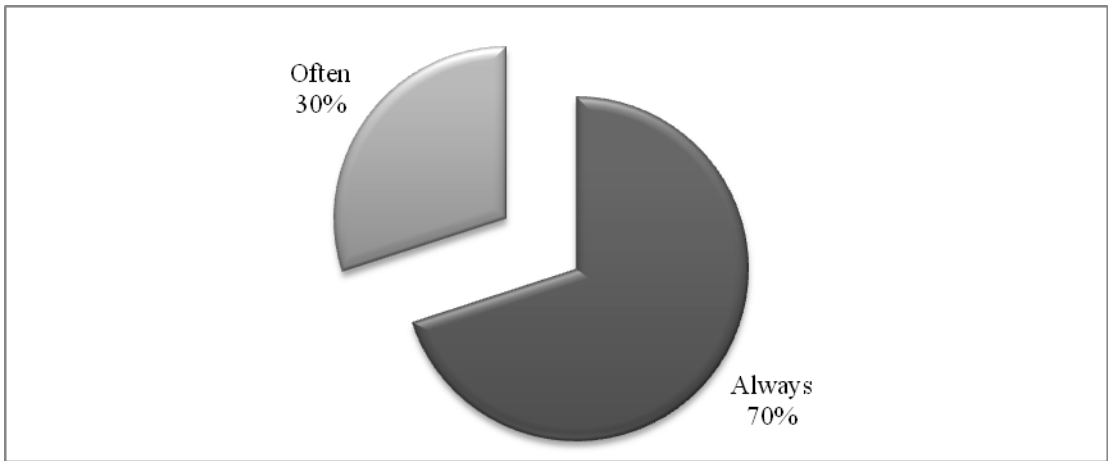

Figure 3.38 Percentage distribution of needing domain specific CAAD software in interior architectural design

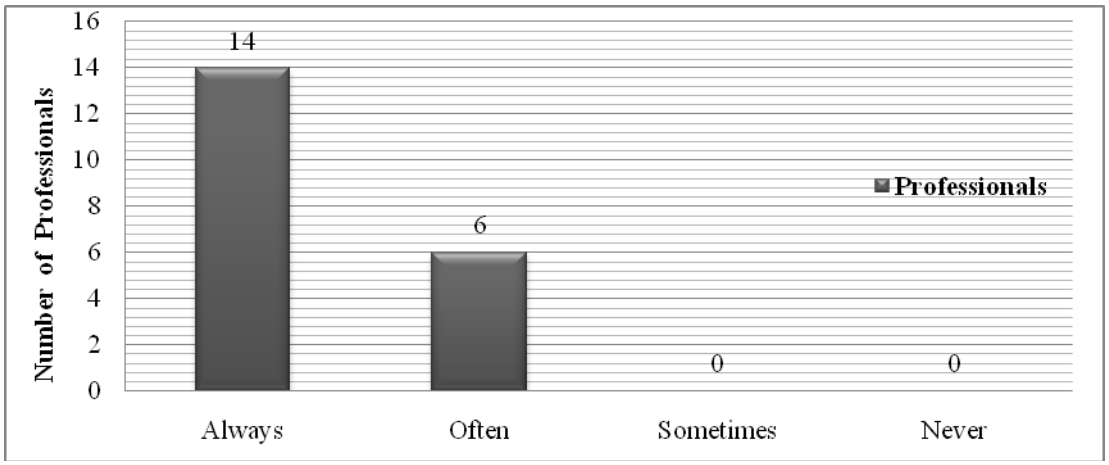

Figure 3.39 Distribution of needing domain specific CAAD software in interior architectural design

In a domain specific package, 'photorealistic rendering' turns out to be one of the most important criteria (Figure 3.40). 'Providing interior architectural details', 'software efficiency', '3D drawing and modeling', and 'ease of use' are the other criteria that professionals seek in a domain specific software.

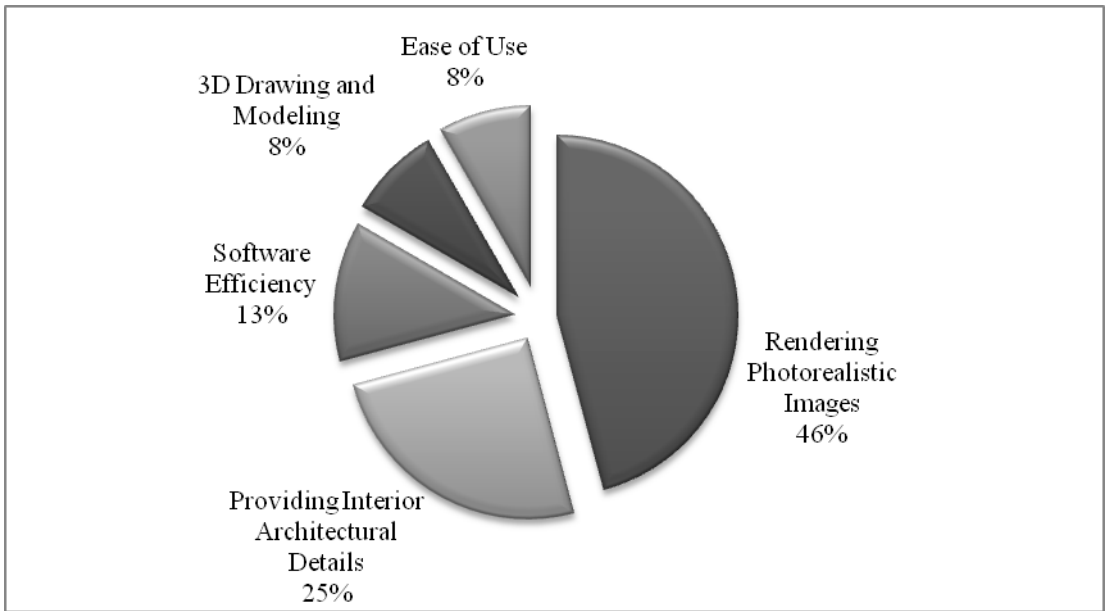

Figure 3.40 Percentage distribution of criteria related to the domain specific CAAD software need in interior architectural design

The interviews reveal that the professionals tend to use a new domain specific software package (Figure 3.41). Although four of the professionals stated that they do not want to use another domain specific software package, than the one they currently use; others said that they would use new interior architectural domain specific software (Figure 3.42).

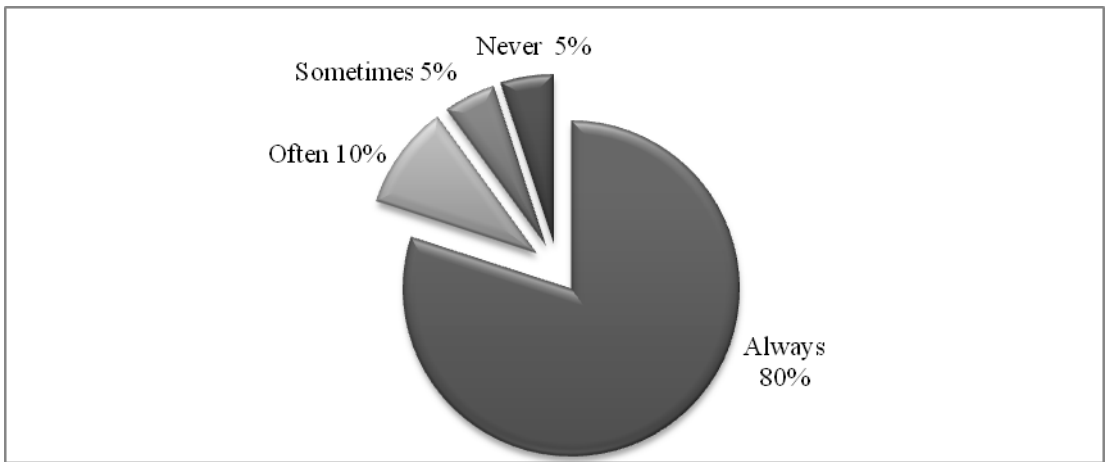

Figure 3.41 Percentage distribution of professionals' tendency in using a new domain specific interior architectural software

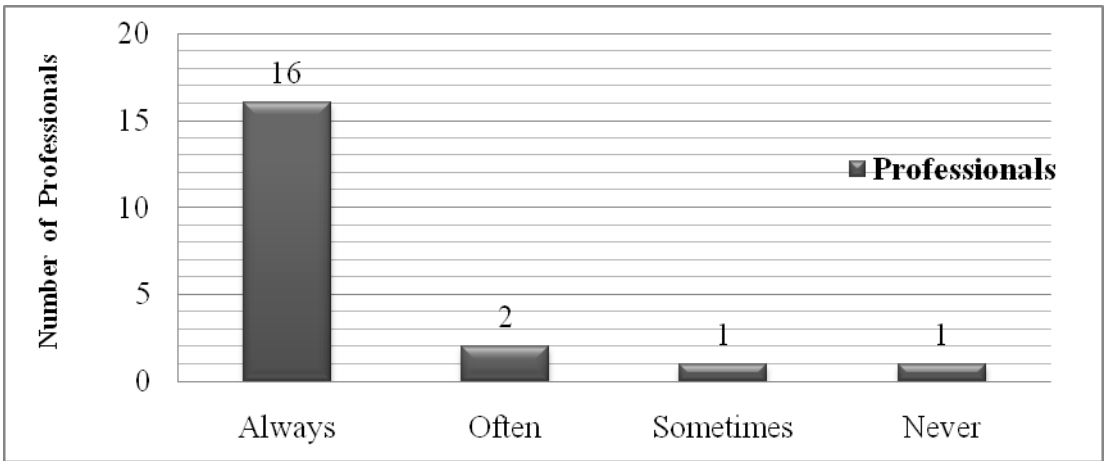

Figure 3.42 Distribution of professionals' tendency in using a new domain specific interior architectural software

At this point, it will be beneficial to mention the criteria selected by the professionals. The percentage distributions of the criteria given in the interview are indicated in Figure 3.43. The results indicate that 'photorealistic image rendering' is the most important criterion selected both by professionals and students. The distribution of preferences of professionals is shown in detail in Figure 3.44.

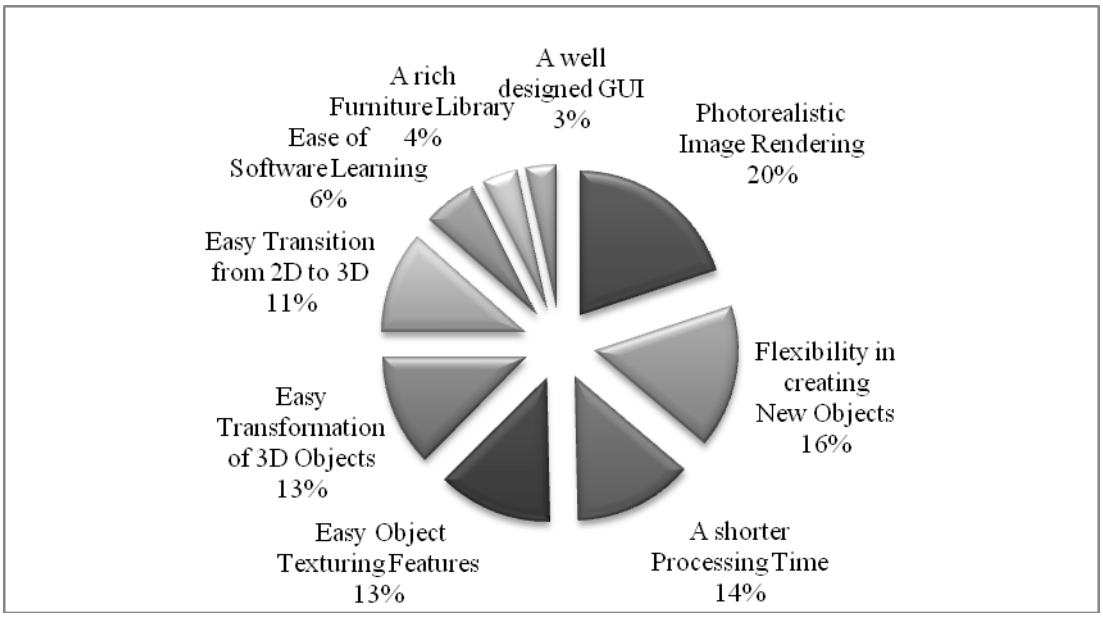

Figure 3.43 Percentage distribution of preferences for using a specific CAAD software

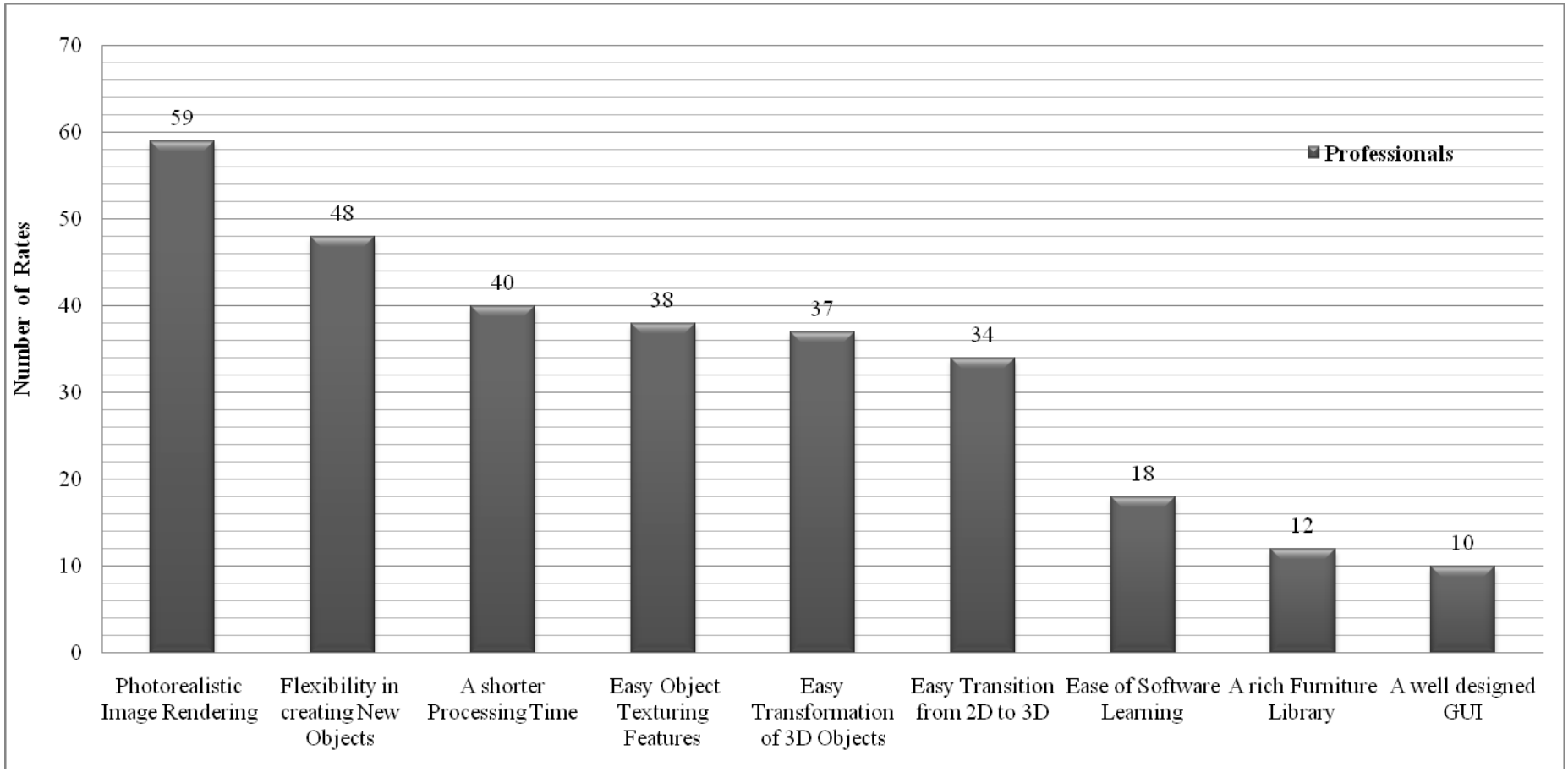

Figure 3.44 Distribution of preferences for using specific CAAD software

Besides the criteria stated in the interview, professionals were asked to state their own requirements from a software package. The answers were examined critically and classified as software features and software quality attributes as mentioned in the questionnaire analyses. Initially, the analyses of needs in software features are presented in Table 3.26. Compared to the students, with professionals there is a surprising decrease in the requirements for 'drawing' features. Although students required specific and extensive architectural and landscape libraries, these features do not exist in the answers of professionals. However, the requirements for 'rendering' features are as popular with the students.

Table 3.26 Professionals' needs in software features

Features	**User Needs**
Drawing Features	Provide an extensive Furniture Library
	Provide 3D Modeling Features and Tools
Transformation Features	Provide extensive 3D Geometrical Transformations
	Provide Transition between 2D and 3D
View Features	Provide Photorealistic View
	Provide Cameras with Video and Animation Features
	Provide different 3D Views and Perspectives
Rendering Features	Provide an extensive Material, Texture and Color Library
	Provide Photorealistic Materials
	Provide Material Editing Features
	Provide various Lighting Elements
	Provide extensive Lighting Features
	Provide Global Rendering (Photorealistic Lighting and Rendering)
	Provide extensive Rendering Features
Other Features	Provide Layering Feature
	Provide Cost Estimation Features

The quality attributes derived from the results of the analysis of professionals' needs are revealed in Table 3.27. Here, 'ease of use' appears less and issues related to 'reliability' seem to disappear compared to students' results. The issues related to 'efficiency', 'flexibility' are stated similar to the quality attributes of the questionnaire analyses.

Table 3.27 Professionals' needs in terms software quality attributes

Quality Attributes	**User Needs**
Ease of Use	Provide easy 3D Object Modeling
	Provide easy Interoperability between 2D and 3D
	Provide easy 3D Object Transformation
	Provide easy Material Editing and Attaching
	Provide easy Software Use (Commands)
	Provide easy Interface Use and Perception
	Provide easy Software Learning
Efficiency	Provide a shorter Processing Time (Quality in Result)
	Provide a shorter Rendering Time
Flexibility	Provide Flexibility in creating New Objects (instead of object library)
	Provide Flexibility in allowing users to Draw Every Shape (especially in Furniture Details)
	Provide Flexibility of Software
Other Attributes	Provide Interoperability between different Software Packages

Percentage distribution of these software features and quality attributes represents that 'ease of use' again is the most important feature among professionals, as in the case of students (Figure 3.45). However, the percentage distribution of 'rendering' with 17%, 'efficiency' with 14%, 'view' and 'flexibility' with 14% are close to 'ease of use'. Figure 3.46 gives detailed knowledge about software features and quality attributes.

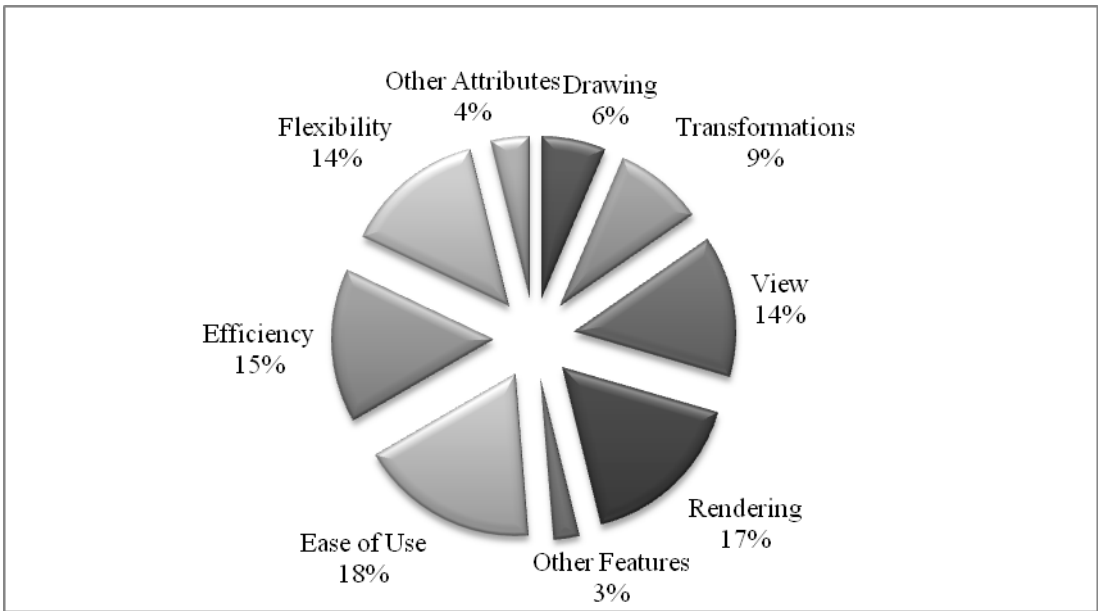

Figure 3.45 Percentage distribution of professionals' needs in software features and software quality attributes

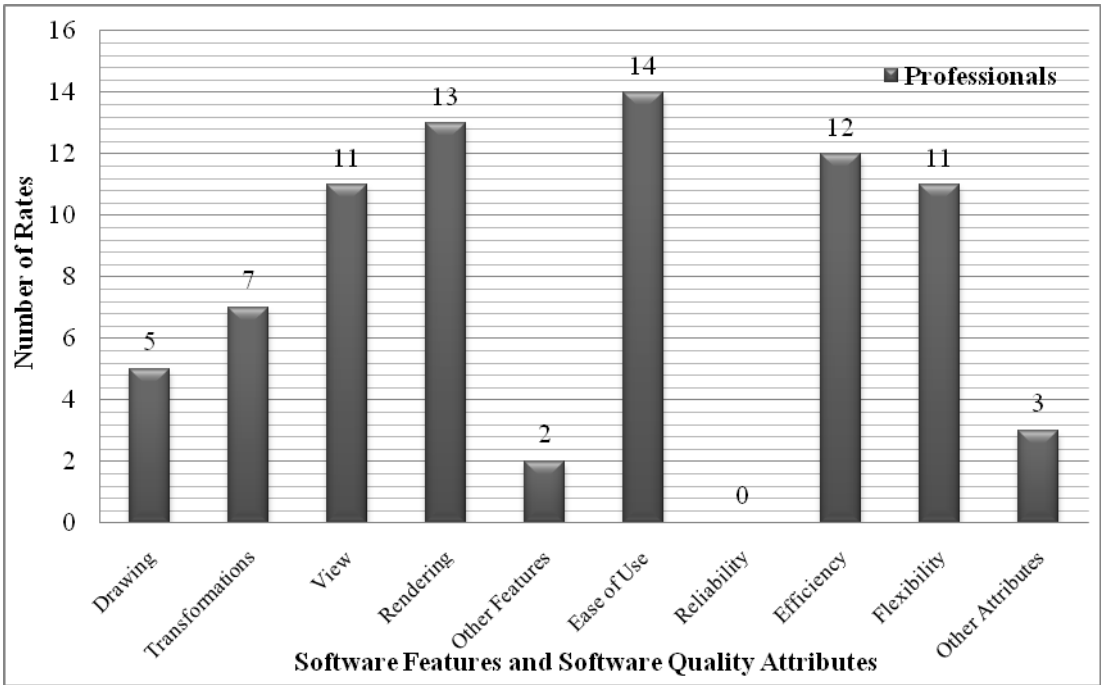

Figure 3.46 Distribution of professionals' needs in software features and software quality attributes

The findings of the interviews that are performed with professionals reveals the following issues;

- AutoCAD is considered to be the most used CAAD software in interior architectural practice, even though other software packages exist.
- Similarly, in all of the interior architectural design phases mentioned, again AutoCAD foreruns in front of other software packages.
- AutoCAD's success in *conceptual design* phase is due to its 'flexibility' and 'sufficiency in 2D drawing' features, and '2D graphical presentation' quality.
- In the *project development* phase, AutoCAD's 'ease of use', its potential for providing 'detailed and technical drawings' and in providing 'precise drawings for production' makes it popular.
- 'Shorter processing time' and AutoCAD's sufficiency in '3D modeling and presentation' features are the most important factors in preferring AutoCAD in *presentation phase.*
- Furthermore, the analyses examined in this part underlined that the professionals find the general purpose CAAD software adequate in spite of its insufficiencies, such as; 'limiting the interior architectural design' and 'lack of interior architectural details'.
- On the other hand, professionals also stated that they need domain specific software package that would provide 'photorealistic image rendering' and 'interior architectural details'.
- In addition, 'photorealistic image rendering' appears to be the most significant requirement among the user needs stated.

- Lastly, when the user needs are classified as ‘software features’ and ‘quality attributes’, although the percentage distributions are close, ‘ease of use’ is the most popular one.

4. PROPOSED MODEL

This chapter introduces a model based on the analyses given in the previous chapters. Initially, three main procedures are introduced for proposing a software model specific to interior architectural domain (Figure 4.1). The model is established as combination of existing general purpose and domain specific software features (as introduced in chapter 3.1.2.1 and 3.1.2.2), interior architectural specific requirements (as discussed in chapter 3.1.2.3) and elicitation of user backlog (as assessed in chapter 3.2.1.4 and 3.2.2.4).

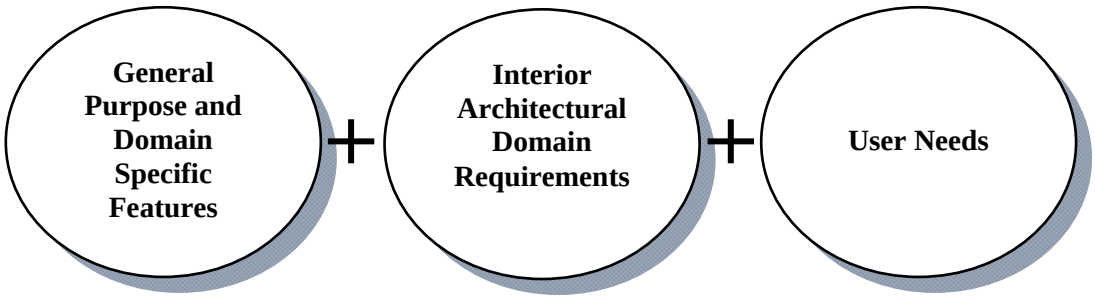

Figure 4.1 Software model procedures

Combining above items, the proposed model is formed by re-evaluating the software features and quality attributes (Figure 4.2). These features and attributes are based on the analysis of existing general purpose CAAD software, as introduced in chapter 3.1.2. However, while doing so, gaps and overlaps between general purpose and domain specific CAAD software features are monitored and integrated into the

model. Moreover, software features and quality attributes of the proposed model are improved by user interviews and questionnaire results.

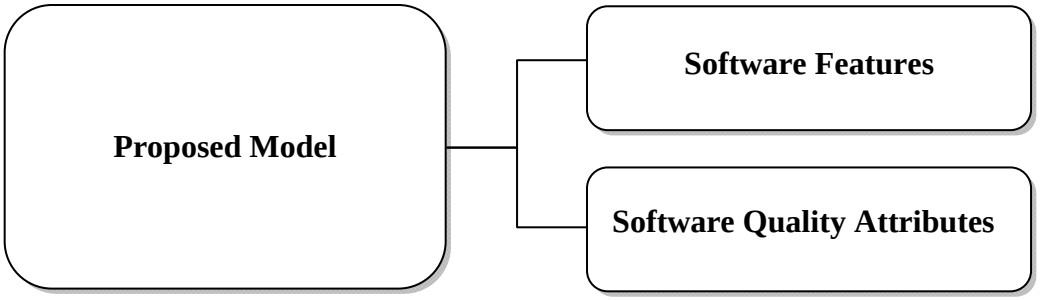

Figure 4.2 Components of the proposed model

Figure 4.3 represents the components of the software features and quality attributes of the model. Software features include detailed information about ‘drawing’ ‘transformation’, ‘view’, ‘rendering’ and ‘other’ features. Software quality attributes of the model include ‘ease of use’, ‘reliability’, ‘effectiveness’, ‘flexibility’ and ‘other’ attributes.

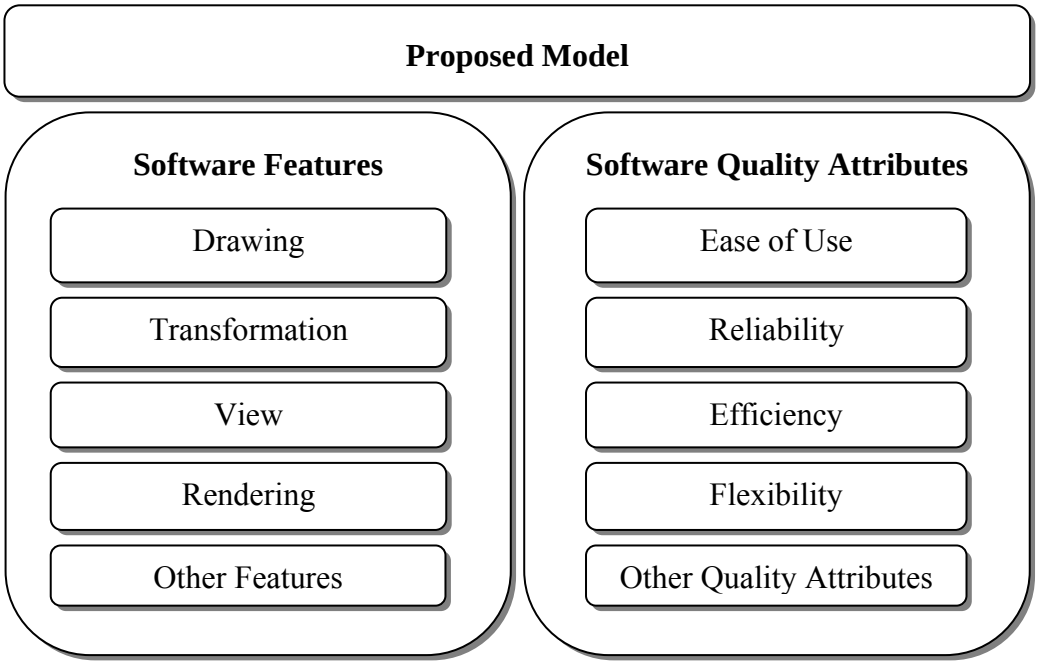

Figure 4.3 Components of the software features and quality attributes

4.1 Features of the Proposed Model

The features of a software package describe how an application behaves under particular circumstances. Therefore, the proposed model will be evaluated according to its; ‘drawing’, ‘transformations’, ‘view’, ‘rendering’ and ‘other’ features. Figure 4.3 represents an overall picture of this feature categorization and their dependency to each other. Existence of any item depends on the existence of another item. For instance, ‘transformations’ can not be applied unless there is an object in the scene. Following tables and figures include the details of each feature item.

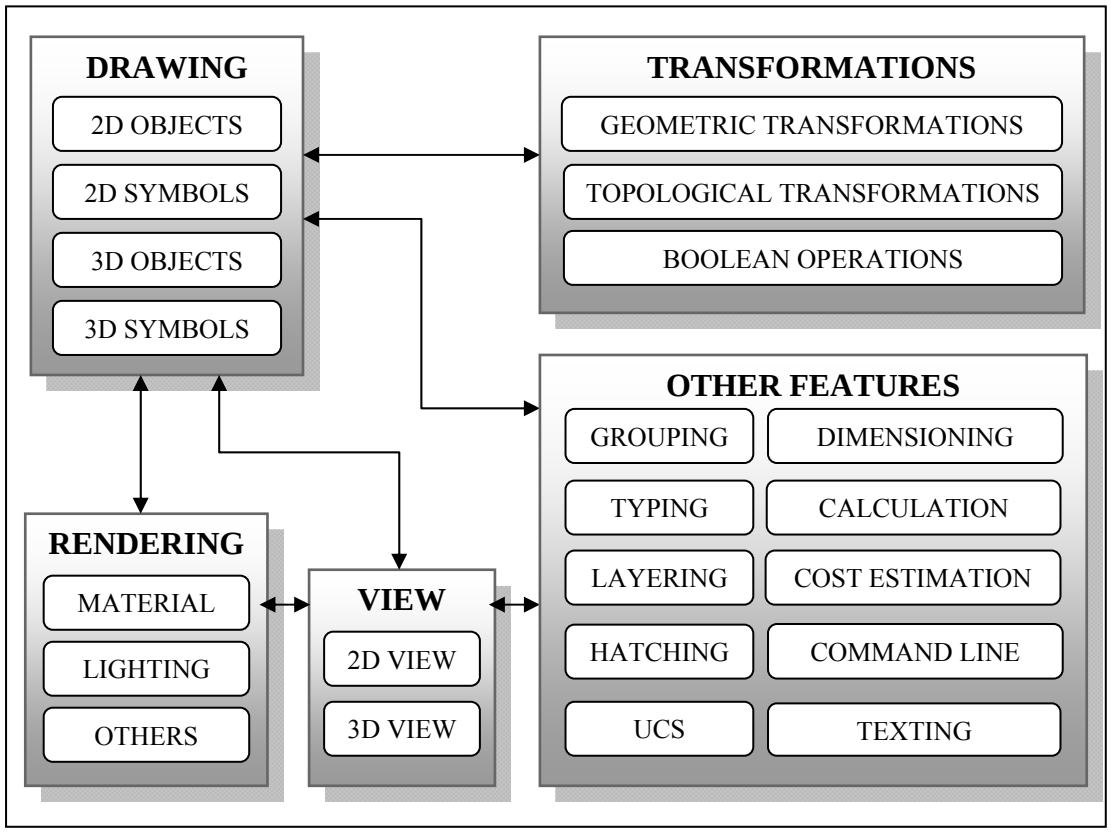

Figure 4.4 Features of the proposed model

Drawing features consist of 2D and 3D objects, and symbols (Table 4.1). The items marked with (o) sign represents the optional items in proposed model that exist in general purpose software but absent in domain specific ones. Moreover, the star (*) signs represent the new items appended to drawing features defined. The results of CAAD software analysis show that these star signed items do not exist in general CAAD software packages. On the other hand, most of the significant domain specific CAAD software used in practice contains those appended features. The new items are significant in that, they give clues about interior architectural domain requirements which are lacking in general purpose CAAD software. These new items are also collected from user requirements during questionnaires and interviews and merged with other features.

Table 4.1 ‘Drawing’ features of the proposed model

	Proposed Model	
DRAWING FEATURES	2D Objects	Line Types
		Shapes
		Grids
		Dimensions
	2D Symbols	Architectural Symbols
		Engineering Symbols
		Landscape Symbols
		Kitchen Symbols *
		Bathroom Symbols *
		Furniture Symbols *
		Accessories *
	3D Objects	Planes
		Volumes
		Quadric Surfaces (o)
		High order Surfaces (o)
	3D Symbols	Architectural Symbols
		Landscape Symbols
		Engineering Symbols *
		Kitchen Symbols *
		Bathroom Symbols *
		Furniture Symbols *
		Accessories *

It is important to point out that, new items appeared in the ‘drawing’ features, are specific parts of architectural buildings, such as kitchen and bathroom. In interior architectural education and practice, there is a need not only for drawing these items from a library, but also for creating new 2D and 3D symbols and transforming them.

In the analysis of ‘transformation’ features, the features in general purpose CAAD software are seemed to be enough and comprehensive compared to domain specific CAAD applications (Table 4.2). Interior architectural CAAD software presents

limited features to the users. Thus, interior architectural students and professionals prefer general purpose CAAD software for more flexible designs. Besides, especially 'topological' transformations gain importance in the analysis of user needs. As a result of this situation, the 'transformation' part of the model is composed of a list of unified features of the analyzed general purpose software packages and user needs.

Table 4.2 'Transformation' features of the proposed model

	Proposed Model	
TRANSFORMATION FEATURES	Geometric Transformations	Copy
		Mirror
		Array
		Offset
		Erase
		Move
		Scale
		Rotate
		Stretch
		Extend
		Trim
		3D Mirror (o)
		3D Array
		3D Move
		3D Rotate
	Geometric Deformations	Bend (o)
		Taper (o)
		Twist (o)
	Topological Transformations	Extrude (o)
		Sweep (o)
		Loft (o)
		Wave (o)
		Noise (o)
	Boolean Operations	Union
		Subtract
		Intersect

Next, in ‘view’ feature analysis, the general outline is again based on general purpose CAAD software. Also, the results of users needs presented in the previous chapter revealed that ‘view’ operations gain importance during *presentation phase* of design process and the important features for users are ‘photorealistic view’, ‘camera’, ‘animation’ and ‘perspectives’ (Table 4.3).

Table 4.3 ‘View’ features of the proposed model

	Proposed Model	
VIEW FEATURES	2D View	Zoom
		Pan
		2D Wireframe
		2D Hidden (o)
		Viewports
		Section View
	3D View	3D Wireframe
		3D Hidden
		Shaded
		Perspective View
		Axonometric (o)
		Section View
		3D Orbit
		Camera
		Animation

‘Rendering’ features consist of three main parts: ‘material’, ‘lighting’ and ‘rendering methods’. Among others, ‘photorealistic rendering’ is the most important feature in the analysis of user needs. In order to obtain a ‘photorealistic rendering’, the materials, textures, colors and lighting should be realistic. Thus, in the proposed model, most of the features include ‘photo-real’ factor (Table 4.4).

Table 4.4 ‘Rendering’ features of the proposed model

	Proposed Model	
RENDERING FEATURES	Material Library	Photo realistic texture library *
		Photo realistic color library *
		Extensive library catalog *
	Material Operations	Material Creation
		Material Editing
		Material Import
		Mapping Direction
		Mapping Frequency
		Texture Mapping
	Lighting Elements	Spotlight (o)
		Direct Light (o)
		Sunlight
		Omni
	Light Editing	Radiosity
		Intensity
		Brightness
		Shading
		Reflection
		Refraction
		Resolution *
	Rendering Method	Local Rendering
		Global Rendering

Furthermore, proposed model also include ‘grouping’, ‘typing’, ‘layering’, ‘hatching’, ‘dimensioning’ and ‘calculation’ under the heading ‘other features’ (Table 4.5).

Table 4.5 ‘Other’ features of the proposed model

	Proposed Model
OTHER FEATURES	Grouping
	Typing
	Layering
	Hatching
	Dimensioning
	Calculation (area etc.)
	Cost Estimation *
	Command Line *
	User Coordinate System (o)

4.2 Quality Attributes of the Proposed Model

Quality attributes of the model cover only the issues regarding the quality of the software. These attributes involve issues related to ‘ease of use’, ‘efficiency’, ‘reliability’, ‘flexibility’ and ‘other’ attributes (Figure 4.4) which are gathered through the questionnaire and the interview analysis.

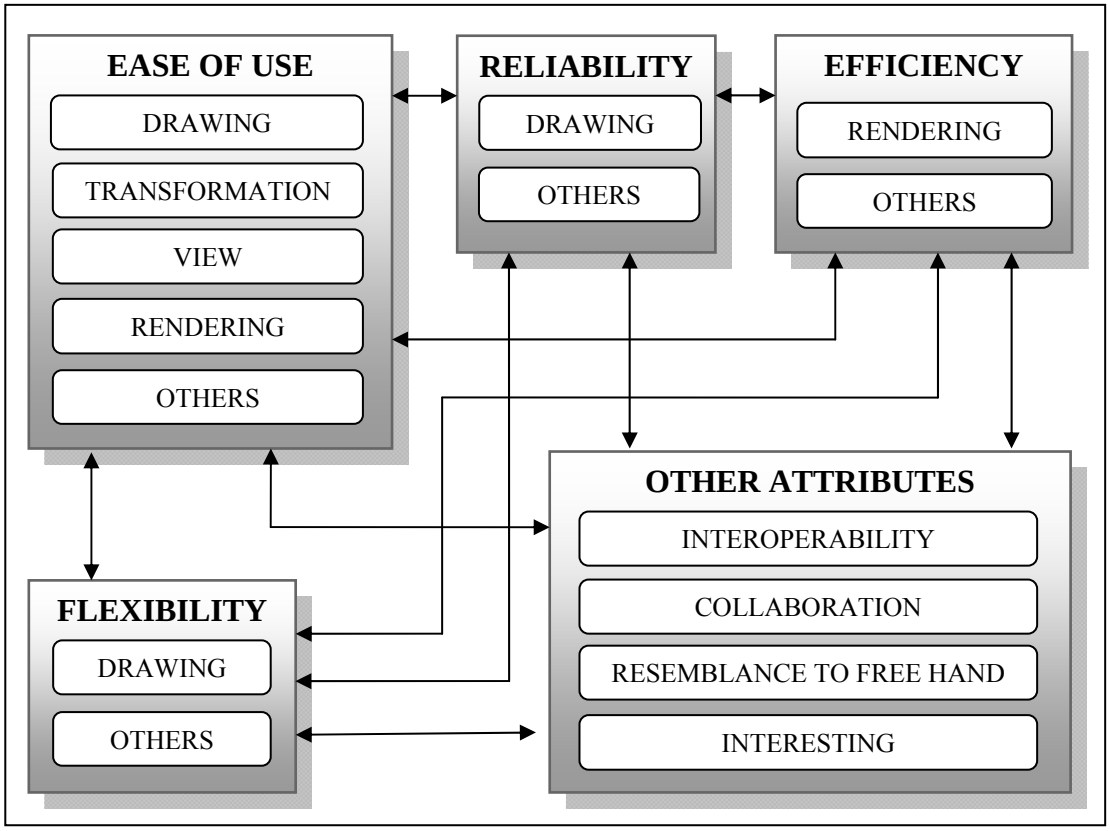

Figure 4.5 Quality attributes of the proposed model

Initially, quality attributes include issues related to the 'ease of use'. It is observed that among the findings of the questionnaire and the interviews 'ease of use' is the most significant attribute among others. Issues related to 'ease of use' involves user-friendly handling of the software and its features, like; 'drawing', 'transformation', 'view' and 'rendering' (Table 4.6). Students and professionals mostly stated that a software package should provide 'easy of use' in terms of 'handling the software and its commands', 'easy interoperability between 2D and 3D', and 'ease of learning'.

Table 4.6 ‘Ease of use’ attribute of the proposed model

	Proposed Model	
EASE OF USE	Drawing	Ease of 3D Object Modeling
	Transformation	Ease of 3D Object Transformation
		Ease of Interoperability between 2D and 3D
	View	Ease of 3D Object View
	Rendering	Ease of Material Editing and Attaching
		Ease of Light Editing
		Ease of 3D Object Rendering
	Others	Ease of Use
		Ease of Interface Perception
		Ease of Learning

The second quality attribute ‘reliability’ can be defined as the working of the system without errors and failures while preventing data loss from the system. In the proposed model software ‘reliability’ is interpreted as the systems’ being ‘reliable during 2D and 3D drawing’ and ‘reliable in recovering mistakes’ (Table 4.7). This interpretation is based on the findings of the student’s questionnaires.

Table 4.7 ‘Reliability’ attribute of the proposed model

	Proposed Model	
RELIABILITY	Drawing	Reliable in 2D Drawing
		Reliable in 3D Drawing
	Others	Reliable in Recovering Mistakes

Another quality attribute is software ‘efficiency’ which comprises the issues concerning the functioning of the system in a comparatively shorter processing time. Software ‘efficiency’ together with the user performance and knowledge is a significant factor in shortening the design and presentation time of the project. Here in the proposed model, ‘shorter rendering and processing time’ with high quality in the result are the criteria presented to improve the software quality (Table 4.8).

Table 4.8 ‘Efficiency’ attribute of the proposed model

	Proposed Model	
EFFICIENCY	Rendering	Shorter Rendering Time
	Others	Shorter Processing Time
		Quality in Result

‘Flexibility’ is another attribute affecting the software quality. Within the context of this study, ‘flexibility’ of the proposed model depends on how much freedom the system provides for its users in designing the intended shape, geometry or project. ‘Flexibility’ is an important factor in interior architecture which is a discipline emphasizing the importance of design and creativity. Thus the issues included in the ‘flexibility’ attribute are the flexibility in ‘creating new objects’ and ‘new forms and shapes’, instead of using them from an object library (Table 4.9).

Table 4.9 ‘Flexibility’ attribute of the proposed model

	Proposed Model	
FLEXIBILITY	Drawing	Flexibility in creating New Objects
		Flexibility in creating New Forms and Shapes
	Others	Flexibility of the Software

Finally there exist, some quality attributes that are not categorized under the attributes already mentioned. These attributes emphasize:

- The need of ‘interoperability’ between different software packages,
- The ‘collaboration’ of users during project design,
- The attractiveness of the software,
- The resemblance to hand drawing (see Table 4.10).

Table 4.10 ‘Other’ quality attributes

	Proposed Model
OTHER QUALITY ATTRIBUTES	Interoperability
	Collaboration
	Interesting Software
	Resemblance to Hand Drawing

4.3 Discussions

The proposed model emphasizes the significant features and quality attributes in order to develop an interior domain specific software package. The significant features are determined by the analysis of general purpose and domain specific software, and by the analysis of the user needs from the questionnaires and the interviews. This model highlights several points about ‘drawing’, ‘transformation’, ’view’, ’rendering’ and ‘other’ features while arousing new discussions about its ‘ease of use’, ‘efficiency’, ‘reliability’, ‘flexibility’ and ‘other’ quality attributes.

Initially, in the ‘drawing’ features, the main gap between the general purpose and domain specific software is revealed to be the capability of drawing 2D and 3D interior architectural elements, like kitchen, bathroom, furniture and accessories. Actually, as the analysis in the chapter 3.2.2 indicates, these interior architectural elements already exist in the currently used domain specific software. Nonetheless, the user has only ability to draw these items from a pre-defined object library in domain specific software. This model differs in this point by providing its users the flexibility to create new objects from these libraries or by modifying these objects in a proper and detailed way.

In the ‘transformation’ analysis, it is revealed that general purpose software involve an extensive feature list compared to domain specific ones. This can be interpreted in two different ways; whether the interior architects do not need this much of transformation features, or the general purpose software introduce too much unnecessary transformation features. To decide whether these features are really of use, a domain specific software should be developed based on the given model and should be tested on both education and practice.

Furthermore, the proposed model improves ‘rendering’ features of general purpose software by adding ‘photorealism’ to ‘material library’ and ‘light editing’ features. The ‘photorealism’ issue has an important part in the formation of the proposed model. The students and the professionals want to visualize their projects as real-looking as possible, not in sketch view. Therefore, this model provides and emphasizes the need for ‘photorealistic’ interior views, which will improve their visual communication between their instructors, their colleagues and their customers.

Besides, the model introduces a new feature ‘cost estimation’, which is lacking in the analyzed general purpose CAAD software. However, it is an inevitable feature in domain specific software used in practice. Because, in real life, professionals have to calculate the approximate or exact value of the project with all expenses included and present this value to their customers. It may be asserted that this new feature in the proposed model will be useful for the students and will make the adaptation to the professional practice easier.

The proposed model also highlights the importance of the quality attributes in development of a software package. Foremost, the attributes related to ‘ease of use’ differentiates the model from other software existing in education and practice.

Also, ‘reliability’ and ‘efficiency’ related attributes that support 2D drawing and 3D modeling in the proposed model are aimed to help in generating more sufficient and faster interior architectural projects in a relatively short time.

Especially, the ‘flexibility’ related attribute of the model in allowing designers to create new forms and shapes, is expected to result in various advantages in a discipline as interior architecture. Interior architects and interior architectural students deal with every small detail in their projects from lighting to furniture details. But, they may not still manage to draw small furniture details with the possibilities current CAAD software offer. If the software is designed as a flexible system, it is expected to allow users’ imagination to develop while presenting new design alternatives.

The ‘other’ quality attributes are seldom considered to be very important ones. However, these are vital items for the future generations of a software package and actually a software model can be developed considering only one of these items.

There are, however, some other important issues that may contribute to the development of this model, which did not come up in the user analyses. These issues are brought up by the author, assessing the existing software packages based on her past experience in the market. With the emergence of computer assisted drawings, the importance of presentation grows in interior architectural education and market. Having a realistic and impressive presentation makes instructors, students and customers more satisfied. Consequently, the users will force the limits of software employed. Software packages may not only be used for presenting images, but also for generating simulations, animating how people will use or how the interior will behave when the project is realized. Software packages, embellished with simulation possibilities such as representing the behavior of water in the inside or the outside conditions (sun, wind, rain, etc.), or assessing the acoustics behavior of an interior will be of much use in the near future. Such packages may even be used to show the lighting quality of an interior environment whether with lights reacting to sensors, or different conditions. In addition, for interior architects it may be beneficial to model objects using realistic and complex geometries rather than quadric surfaces. These are high-order surfaces, including spline fits, curved surfaces, patches and grid representations. It may be assumed that the requirements about simulations and high-order surfaces will become common place soon in interior architectural education and practice. Although these requirements may be difficult and time consuming to be integrated into the software, and may increase the price of the software, a software

model should integrate these requirements in order to compete with the current technological developments. Consequently, a domain specific software package should address all of the interior architectural design phases and design purposes in order to have a complete tool in design and education.

The proposed model may well be developed by future studies. It needs to be noted that this model constitutes a framework intended for users, not for software developers. Therefore, a software developer may utilize this model in order to develop an interior architectural domain software package. Also, the software developed based on the model should be assessed among the interior architectural students and professionals. Changes in the requirements of the users may be expected after they use the software.

Furthermore, the assumptions of this study are limited due to the absence of a structured observation with interior architectural students and professionals while they are using the specified software. Within the scope of this study, structured observation has not performed with the students. However, only in the practice, the author of this thesis makes some observation with her colleagues while utilizing these software. In a future study, this observation may be useful for the development of this proposed model.

Moreover, the interface design, and the menu issues are not mentioned within the context of this thesis. A future study might be based on these issues in order to develop adequate formats for interior architectural domain software.

5. CONCLUSION

Today every single discipline needs computational help. Computer aided working environments seem one step ahead from the non-computerized ones in meeting the contemporary requirements of the era. On the other hand, getting a relevant service from computers stands at the heart of professionalism. Otherwise, users may be faced with unpleasant situations due to the lack of proper tools. A specialized tool is always preferred compared to a general purpose one. This study underlines this point and discusses the absence of specialized software for interior architecture.

In this thesis, the discussion is shaped around one question of whether there is any relevant and a fully designed and dedicated software package to interior architecture. At the very beginning, a short history of interior architecture is given to illustrate where the roots of interior design lie and its emergence as a new discipline within architecture. It is seen that although interior architecture is separated from architecture, it still depends on architecture in some issues, as in the case of software. Being a discipline with issues different than those of architecture, this study introduces important requirements such as the need for some specific CAAD software for interior architects' use.

This study tries to determine the specific issues to be taken into consideration while establishing software for interior architecture. These are; analysis of the most

commonly used interior architectural CAAD software packages and their features, analysis of the interior architectural domain requirements, and analysis of the user needs gathered from questionnaires and interviews both in the education and practice.

Initially, the commonly used CAAD software in interior architecture is analyzed and classified as general purpose and domain specific. Also, the feature lists of existing general purpose and domain specific CAAD software are compared in order to reveal their sufficient and insufficient features that are intended to be useful for interior architectural purposes. It is found that while general purpose ones are more detailed in 'transformation', 'view', and 'rendering features', the domain specific ones are detailed in 'drawing' features and elements. A unified feature list might be a solution for displaying all features.

Furthermore, user needs show most interior architects try to utilize general purpose CAAD software through customization. The students and professionals use either general purpose CAAD software or customized/improved versions of those software packages. However, despite their reputation in CAAD industry, most general purpose CAAD software packages can sometimes fail to solve real life problems of interior architects. This thesis underlines the necessity of domain specific software for interior architectural design purposes and procedures.

User questionnaire and interviews served for the purposes of this thesis in many respects. Requirement elicitations provide a list of software features and quality attributes that were confirmed by students and professionals. Most of the critics

addressed the lack of interior architectural elements for several specific parts of the buildings and lack of photorealistic image rendering. One of the mentioned critical points was the ‘ease of use’ attribute. Users had complains about the ‘ease of use’ of CAAD software, claiming that general purpose CAAD software does not assist in a user friendly fashion. Here it might be suggested that in an interior architectural specific CAAD software package there would be a large set of built in interior architectural libraries and proper tools for photorealistic rendering. Thus, it would be easy to operate in a flexible manner.

After gathering features of the CAAD software and the user needs, the following chapter of the thesis is dedicated to the proposed model. This proposed model aims at resolving the conflicts between general software packages and puts user needs on top of the solution stack. The proposed model is presented based on a feature and quality attribute list in relation to the end users. However, a software engineering approach should not be expected at any level.

To sum up, all researches and analyses given with this thesis infer that there is an absence for domain specific CAAD software in the education and market dedicated to interior architecture. The concluding proposed model is extracted from the results of the analyses of many general purpose and domain specific software packages, and a large questionnaire and interview in a wide spectrum of users. This model can be used as a reference for the future implementations in order to realize specific CAAD software for interior architects to meet their needs and to augment to solve their real life problems.

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APPENDICES

APPENDIX A

A.1 Questionnaire

Full Name : .....
Class : ☐ 3rd ☐ 4th
Gender : ☐ Female ☐ Male
Date of Birth : .....

---

1) How long have you been using CAAD software for your interior architectural project design and presentation purposes?

☐ Year(s): .....
☐ Never used

2) Which of this following software do you use most for your interior architectural project design and presentation?

☐ AutoCAD	☐ Arcon	☐ 3D Home
☐ 3D Studio MAX	☐ SketchUp	☐ 3D Architect
☐ ArchiCAD	☐ Rhinoceros	☐ Design Workshop Lite

Other(s): …….

3) Please indicate the software programs you use during the project design phases stated. (You can write more than one program for each phase).

Conceptual Design Phase	
Design Development Phase	
Presentation Phase	

In the following questions 4 to 9, please fill in the blanks regarding your experience in the field:

4) In the conceptual design phase I mostly use ....., because.....

5) In the conceptual design phase I rarely use ....., because.....

6) In the project development phase I mostly use ....., because.....

7) In the project development phase I rarely use ....., because.....

8) In the project presentation phase I mostly use ....., because.....

9) In the project presentation phase I rarely use ....., because.....

10) When do you think the general purpose CAAD software such as AutoCAD, 3D Studio MAX, ArchiCAD are wholly adequate for developing interior architectural projects?

☐ Always
☐ Often
☐ Sometimes
☐ Never

11) When do you think it is important to benefit from domain specific purpose software (supporting furniture, color, texture, material, 3D features) as you are designing an interior architectural project?

☐ Always
☐ Often
☐ Sometimes
☐ Never

12) Please order the following features of CAAD software you preferred to use in your interior architectural project design and presentation from (5) the most important to (1) the least important.

..... A well designed graphical user interface
..... A rich furniture library
..... Easy transition between 2D and 3D
..... Easy transformation of 3D objects
..... Easy object texturing features
..... Capability of designing new objects
..... Capability of rendering photorealistic images
..... Ease of learning
..... A shorter processing time

13) Which features/functions do you wish to have in software you use for your interior architectural project?

.....
.....
.....

14) Would you be interested if you were announced a new CAAD software specifically released for interior architectural purposes?

☐ Always
☐ Often
☐ Sometimes
☐ Never

Thank you.

A.2 Interview

Company : .....
Full Name : .....
Profession : .....
Gender : ☐ Female ☐ Male
Date of Birth : .....

---

1) How long have you been using CAAD software for your interior architectural project design and presentation purposes?

☐ Year(s): .....
☐ Never used

2) Which of this following software do you use most for your interior architectural project design and presentation?

☐ AutoCAD	☐ Arcon	☐ 3D Home
☐ 3D Studio MAX	☐ SketchUp	☐ 3D Architect
☐ ArchiCAD	☐ Rhinoceros	☐ Design Workshop Lite

Other(s): …….

3) Please indicate the software programs you use during the project design phases stated. (You can write more than one program for each phase).

Conceptual Design Phase	
Design Development Phase	
Presentation Phase	

In the following questions 4 to 9, please fill in the blanks regarding your experience in the field:

4) In the conceptual design phase I mostly use ....., because.....

5) In the conceptual design phase I rarely use ....., because.....

6) In the project development phase I mostly use ....., because.....

7) In the project development phase I rarely use ....., because.....

8) In the project presentation phase I mostly use ....., because.....

9) In the project presentation phase I rarely use ....., because.....

10) When do you think the general purpose CAAD software such as AutoCAD, 3D Studio MAX, ArchiCAD are not wholly adequate for developing interior architectural projects?

☐ Always
☐ Often
☐ Sometimes
☐ Never (They always meet my needs)

Why?
.....

11) When do you think it is important to benefit from domain specific software (supporting furniture, color, texture, material, 3D features) as you are designing an interior architectural project?

☐ Always
☐ Often
☐ Sometimes
☐ Never

Why?
.....

12) Please order the following features of CAAD software you preferred to use in your interior architectural project design and presentation from (5) the most important to (1) the least important.

..... A well designed graphical user interface
..... A rich furniture library
..... Interoperability between 2D and 3D
..... Easy transformation of 3D objects
..... Easy object texturing features
..... Capability of designing new objects
..... Capability of rendering photorealistic images
..... Ease of learning
..... A shorter processing time

13) Which features/functions do you wish to have in software you use for your interior architectural project?

.....
.....
.....

14) Would you be interested if you were announced a new CAAD software specifically released for interior architectural purposes?

☐ Always
☐ Often
☐ Sometimes
☐ Never

Thank you.

APPENDIX B

B.1 CAAD Software used in Interior Architecture

Software Name	Software Company	Website
20-20	20*20 Technologies	www.2020technologies.com/
3D Home Architect	Broderbund	http://www.3dhaonline.com/
3D Studio MAX	AutoDesk	www.autodesk.com/3dsmax/
Adeko	Adeko Group	www.adeko.com.tr/
Allplan	Nemetschek Systems	http://www.nemetschek.co.uk/
ArchiCAD	Graphisoft	www.graphisoft.com/
Arcon	Eleco	www.arcon-software.com/
AutoCAD	AutoDesk	
Carrara	DAZ 3D	http://www.daz3d.com/
Corel Draw	Corel	http://www.corel.com/
Design Workshop Lite	Artifice Inc.	http://www.artifice.com/
Infowood	Design Effective	http://www.e-kitchendesign.com/
IntelliCAD	IntelliCAD	http://www.intellicad.org/
Kareo	White CAD	http://www.whitecad.com/
Kitchen Draw	Kitchen Draw	www.kitchendraw.com/
Maya	AutoDesk	www.autodesk.com/maya/
Microstation	Bentley	http://www.bentley.com/
Outline 3D	Parallel Graphics	http://www.outline3d.com/
Photoshop	Adobe	www.adobe.com/
Rhinoceros	Robert McNeel & Ass	www.rhino3d.com/
SketchUp	Google	www.sketchup.com/

B.2 Some Examples of Interior Architectural Drawings

1. A sample interior drawing produced by ‘ArchiCAD’ rendered by Artlantis

Retrieved from www.graphisoft.co.nz/.../products/artlantis.aspx

2. A sample interior drawing produced by ‘SketchUp’

Retrieved from http://www.sketchup.com/index.php?id=20&gid=376#top

3. A sample kitchen drawing produced by ‘Kitchen Draw’

Retrieved from http://www.kitchendraw.com/gallery.htm

4. A sample kitchen drawing produced by ‘Giotto’

Drawn by Burcu Gökçen Bozdağ

5. A sample bathroom drawing produced by ‘Infowood’

Retrieved from

http://www.e-kitchendesign.com/www/ef_d_galleryframe_en.htm

6. A bathroom drawing produced by ‘Kareo’

Retrieved from
http://www.whitecad.com/whitecad/index.php?option=com_zoom&Itemid=29&page=view&catid=2&PageNo=2&key=17&hit=1

7. A sample bedroom drawing produced by ‘Rhinoceros’

Retrieved from http://gallery.mcneel.com/?language=en&i=30149

8. A sample bedroom drawing produced by ‘3D Studio MAX’

Retrieved from
www.creative-3d.net/3DGallery.cfm?Software=3D%20Studio%20Max

LIST OF TERMS

Add Operation	Unifies two or more objects while creating an object based on the total geometry of all.
Animation	The process of making moving pictures
Array	Rectangular or circular arrangement of an object within specified distances of rows and columns, or circular angles
Axis	A principal direction along which the relative movements of a tool or work piece occur.
Axonometric View	Within orthographic projection, axonometric projection shows an image of an object as viewed from a skew direction in order to reveal more than one side in the same picture
Boolean Operations	The basic operations that include union, subtract and intersect operations
Brightness	An attribute of visual perception in a drawing which an object/ a source appears to emit a given amount of light
Chip	A small slice of silicon or other material on which a circuit has been printed
Collaboration	To cooperate or work together
Copy	A function in computer software which allows software, text, drawings or files to be replicated
Dimensioning	Indicating or determining size, angle and position of an object existing in the drawing
Domain Specific Software	A software developed and intended to be useful in a specific task or domain
Drawing	The software feature in order to determine an object or shape
Efficiency	The ratio of the effective or useful output to the total input in any system, or the quality or property of being efficient

Erase	Removes an object or selected objects
Extrude	An operation which transforms 2D objects into 3D by forcing out the plan view of the object into a specified height.
Flexibility	The quality of the software to be adaptable or variable
General Purpose Software	Software designed to be useful for a broad range of tasks or domains
Geometric Transformations	Modifies the properties of the objects, such as shape, coordinates or angle, apart from its topology. 'Move', 'rotate', 'scale', 'reflect' and 'shear' transformations are some of the examples.
Global Rendering	A rendering method that allows having a real time rendering by taking account of every single light source reflecting from each objects on the scene. It is such a technique that advances illumination from one environmental light source to many light sources in order to calculate shading more accurately.
Grids	A two-dimensional structure made up of a series of intersecting vertical and horizontal axes used to structure content in a drawing
Grouping	Provides grouping of 2D or 3D objects as if they react like one object.
Hatching	To shade the defined areas by drawing or etching fine parallel or crossed lines on
Hidden Line	Removes any line hidden from view assuming surfaces are opaque.
Interface	A boundary physical or logical, between two physical or logical systems: e.g. a person and a computer
Interoperability	The ability to exchange and use information between different software to communicate
Intersect Operation	Creates an object from the overlapping geometry of two objects
Isometric View	It is a method of visually representing three-dimensional objects in two dimensions, in which the three coordinate axes appear equally foreshortened and the angles between any two of them are 120°
Layer	Used to categorize information in a drafting system

Layering	An operation that helps to organize drawings in different layers of information, put top of each other like transparencies.
Line	A line is a one-dimensional entity whose extend is designated by length that may exist in a one, two or three dimensional space.
Local Rendering	A rendering method that ignores the transfer of light between objects. Every object is shaded regardless of analyzing whole ray tracing between surfaces.
Loft	A method used for creating a 3D surface by copying a 2D section through an axis
Microcomputer	A stand-alone computer; microcomputers cannot share data unless networked
Minicomputer	A computer larger than a microcomputer which can share data and which can support a number of users
Mirror	Allows an object or selected objects to be reflected through a specified axis
Move	Moves one or more objects selected from their current location to another.
Offset	Copies and relocates a line, circle, arc or polygon at a specified distance from the original object
Quadric Surfaces	The surfaces are generated from conic sections which are the 2D shapes formed when a plane cuts a cone at various angles. Later on, these sections are rotated 180 degree through an axis while generating a surface. Spheres, ellipsoids, hyperboloids, and paraboloids are some of examples of these 3D objects
Quality Attribute	The software properties that affects the quality of the software
Planes	The objects that are defined with three non-collinear points which are flat and are constructed simply by creating a 2D form and extruding this form by length that may exist in a one, two or three dimensional space
Radiosity	A global illumination algorithm used in 3D computer graphics rendering
Ray trace	Traces particles of light to elements on screen. The rendering becomes photo-realistic and casts more hard-lined shadows
Reflection	Returns of a wave of light from an object or a surface that it strikes into the medium through which it has traveled.

Reliability	An attribute of any system that consistently produces the same results, preferably meeting or exceeding its specifications, the quality of being dependable.
Rendering	The process of attaching texture, material and adjusting the light in a drawing in order to maintain an image of the object
Rotate	Draws objects into a new position around a base point with a specified angle
Scale	Allows the size of the objects to be altered
Shaded View	To view the object with its surfaces shaded
Shading	Refers to the process of altering a color based on its angle to lights and its distance from lights to create a photorealistic effect. Shading is performed during the rendering process.
Shear	Produces a distortion on the selected object while maintaining its topology.
Smooth Shading	Renders the difference between surfaces as smooth.
Software	Programs of instructions that tell a computer what to do
Software Feature	Describes how an application behaves under particular circumstances.
Solid Modeling	A modeling method in which solid objects are defined and physical attributes can be assigned to them
Stretch	Used to elongate the length of an object or group of objects
Subtract Operation	Subtracts the selected object from another by creating an object from the remaining geometry.
Surface Model	A model which is composed of infinitely thin planes, used for visualization
Sweep	A method that creates a geometrically complex 3D object through pushing a 2D object through space while revolving it around an axis at the same time
Topological Transformations	Allows for changing the in which the object's topology and its spatial features that are connected to each other. 'Extrude', 'sweep' and 'loft' transformations are the examples of topological transformations

Transformation	The process by which objects properties are converted according to its geometry or topology.
Trim	Eliminates the corners of intersecting lines in a drawing
Typing	A process of grouping objects with similar characteristics to describe a drawing in terms of its parts. Types are associated with non-graphical information such as area, cost, value, etc
User-friendly	An interface which is easy to use
Viewports	Provides top, bottom, front, back, left or right view of the objects
Volumes	The solid objects that are providing parameters like length, width, height, radius to predetermined 3D volumes existing in most of the CAAD software
Wireframe Model	A 3D model built up of lines representing the intersection of planes
Wireframe View	The view of the object by drawing lines at the location of each edge, or where the smooth surfaces meet
Zoom	To cause text or objects in a window or frame to appear larger or smaller on the screen

LIST OF ABBREVIATIONS

2D	Two Dimensional
3D	Three Dimensional
AEC	Architecture, Engineering and Construction
API	Application Programming Interface
BIM	Building Information Modeling
CAAD	Computer Aided Architectural Design
CAD	Computer Aided Design/Drafting
DXF	Data Exchange Format
NURBs	Non-Uniform B-spline curves
PC	Personal Computer: an IBM clone
UCS	User Coordinate System