Research on software selection

*Find the most suitable 3D modeling software*

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Graduate thesis

June 2014
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Date: 26.05.2014
Abstract

Nowadays, with the increasing complexity of the engineering equipment and installations, more and more engineering companies start to take 3D modeling into consideration because of the multiple advantages.

The company can improve efficiency because designers don’t have to redraw the models for different views any more. 3D models are more intuitive and clear than 2D drawings both for designers and non-technical clients. The technology of 3D modeling software develops continuously that the design of interface becomes more and more user friendly and it is more acceptable for non-experienced staff to adapt 3D modeling.

However, there is a large number of 3D modeling software in the market. How to choose the suitable software for the company is the question that many employers wonder. Just trusting the sales literature will decrease the reliability of the decision. This report describes the real case that the thesis student helped a water treatment company to choose a suitable 3D modeling software by software selection method.

It could be the reference to other companies which are confused to choose the suitable 3D modeling software, especially the small companies.
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1. Introduction

1.1 Background

1.1.1 Company Introduction and current situation

AquaControl Nederland B.V. is a water treatment company that designs and builds new installations and serves and maintains existing water treatment systems.[1]

![Logo of AquaControl Nederland B.V.](image)

The company was founded in 2000, which was just a one-man company focusing on serving and maintaining water treatment systems. At that time, paper drawings were enough for marking sizes and general shapes.

With the development of the company, it transferred to start designing and building new installations of water treatment and established the branch in Russia. During the growing of business, the demand of setting up the database of documents and building more accurate drawings with dimensions leaded the first upgrade of company to make digital 2D drawings.

Up to now, when the company design and build the installations, they still make relatively simple 2-D drawings in AutoCAD 2000 and other office software or sometimes drafts on paper. The one reason is the staff of the company have insufficient skills on higher level mechanical drawings, and another is until now they did not really feel the need to upgrade again.

1.1.2 Problem introduction

At this moment, AquaControl just accepted an order to design and build a new installation of EDI system. EDI (Electro De-Ionization) technology removes residual salts and ionizable aqueous species - such as carbon dioxide, silica, ammonia and boron and obtain the almost pure water. The ultrapure water is mainly used in power generation for boiler feed, semiconductors and microelectronics for cleaning agent. It is essential in these industries while not many water treatment companies have the experiences. AquaControl is the company which has the specialty in building the EDI installations.

However a problem appeared that 2D drawings seems to become more and more insufficient for them to develop. On one hand, since EDI installations contain quite large amounts of pipes and the company try to design the installation in smaller space as their advantage, 2D drawings become hard to recognize each stream because they are usually lapped in 2D drawings no matter in which view. It is also hard to detect the interference between the components in 2D drawings. On the other hand, 2D drawings are not attractive and intuitive when demonstrating the system to the clients. A nice show will be another advantage for them when soliciting business.

Although the company still need 2D-drawing function to complete P&ID (Process and Instrumentation Diagram) schemes and electrical schemes of the system, Aquacontrol thought it is the time to take the 3D modeling into account. By using 3D modeling, the company could significantly reduce the complexity of drawings, the time of design, the possibility of errors, and improve the collaboration. These main advantages will increase the efficiency
of drawing and improve the attraction to the clients. Correspondingly, the company could benefit a lot from the less expenses and more orders.

However, as the new software needs a large investment, the company still has the worry whether the upgrade will be successful. In addition, since the staff have insufficient skills on 3D mechanical drawings, they have to face the confusion of choosing the software package which is suitable for them and the worry whether they could handle it in the future use.

1.2 Problem definition

The project is surrounded with the selection of mechanical 3D drawing software. Nowadays, 3D CAD modeling has become a fashion when designing industrial products among the manufacturing industry. AquaControl Nederland B.V. has detected the evolution and wanted to keep up to date.

1.2.1 Aim and actions

The aim of this research is to find a suitable solution for AquaControl to transfer their current drawing method to the 3D modeling.

To address research aim, the specific research actions are presented as follows:

1) To select the suitable mechanical drawing software;
2) To test and argue the fitness of selected software;
3) To prepare the implementation of the software for the company.

1.2.2 Central research question

Which 3D modeling software is most suitable to reduce the cost and meet the demands?

1.2.3 Sub questions

1) What are the cost of the company?
2) What are the requirements and demands of the 3D software?
3) What software are in the market?
4) Which software could match the requirements best?

1.2.4 Desirable situation

As the purpose of the project, a 3D modeling software would be selected and a solution should be designed for the staff in AquaControl in order to implement the software. Meanwhile, the modeling of EDI stack will be finished by the thesis student to prove the feasibility of the software.

1.3 Structure of the text

Following on the introduction of project, the body of report will start with the literature review. In chapter 3, methods that have been put to use in the project will be explained. Each method is designed to execute the research actions in the chapter 1.2.1. In chapter 4, the results linked to the methods will be presented. At last, the conclusion and recommendation about the project will be described in the chapter 5.
2. Literature review

In the literature review, the benefits of 3D modeling are declared again under the support of prior researches. Meanwhile, a previous case study of CAD software selection will be summarized as a reference in the software selection section.

2.1 Benefits of 3D modeling

Under the usage of initial 2D CAD method, there was a high probability that costly design changes would be required before a design got into production (Ertu Unver, 2006)[2]. This problem has been paid more and more attention by many companies, including the AquaControl. Combined with other disadvantages of 2D CAD, 3D modeling has been critiqued as an effective solution to solving them in prior researches.

With 3D CAD software, each individual component of a structure can also be isolated, analyzed, tested, approved or changed—without accidentally altering other design components (Antonio Pascucc, 2012)[3]. The capability of producing three-dimensional representations of objects has allowed designers to shorten the design cycle further because the designed product can be viewed from any angle, assemblies can be analyzed for interference in operation and mass and other properties of the components can be determined accurately before a physical prototype is constructed (Udayan, Amrik and Graham, 1996)[4]. The shorter the design time of a product, the earlier the product can be introduced to the market, which will give the company more possibility to get the orders and gain the profits (Nicos Bilalis, 2000)[5]. Other benefits like giving clients and prospects a virtual tour of their products, and gaining more precision and control are also be described. (Antonio Pascucc, 2012)

2.2 Package selection

Under the situation that 3D modeling will be upgraded to, the prior case of software selection is valuable to be used for reference.

The steps, including the definition of criteria factors, the identification of potential suppliers of software, and the suitability evaluation of potential systems, would be processed before the package was selected.

For the evaluation, the factor rating method using a decision support matrix to evaluate the various software option was designed. The factors, which were developed based on the mission statement, were assigned the weight. Each of the potential software packages was given a score for each of the factors. The scores were then multiplied by the weight, and the result totaled for each package (Udayan, Amrik and Graham, 1996).

2.3 Suitability judgment

As the last assessment of the selected software, a 3D representation of the “typical” products to the company could be taken into consideration, which is also introduced in the case study of 3D CAD upgrade from Udayan, Amrik and Graham (1996).
3. Methods

Corresponding to each action raised in problem description (Chapter 1.2.1), a series of methods have been established and will be introduced and explained in this part. Every suffix number of the sub chapter refers to the corresponding number of the action.

3.1 Software selection method

The project focused on the selection of the suitable software at first, which follows the procedures in figure 3.1 to judge the most suitable one.

For the company, what is the exact key features in the usage of drawing software has been analyzed at the beginning of the procedure. The means included interviews, drawing collection, current software evaluation.

Since the final purpose to conduct this research is to create more profit for the company, a cost investigation was processed as well. In the investigation, the aspects of costs of the company was surveyed and the reduction and increase of cost under the situation of 3D modeling upgrade was evaluated.

In the third step, the task is to match the “core” requirements to possible software packages, and conclude a short-list with possible solutions. The software trial refers to try the user interface, ease of use, function specifications and other valuable points. All the information collected from the trial was processed to conclude the advantages and disadvantages of possible software and then grade the scores to judge to what extent the software match the requirements. At last, the result was produced from the top score of judgment table.

3.2 Suitability assessment

Even though the selected software has the highest score, there is still the possibility that the company don’t satisfied with the capability of the software. Hence, to evaluate the fitness of the software, in the case, an EDI stack was selected to be modeled in the selected 3D software.
The reason to choose EDI stack is that it is the one of the key subject of the drawing, it is fairly complex and it is expected that in the future, designers will work on EDI installations.

3.3 Software implementation

Implementation deals with the transfer of the new software in the company. The aim is to realize the independent operation of new software by the company staff within their demands. The implementation was prepared by the student and will be processed by the company.

The implementation is divided to phases because it contains many procedures. Under the procedures, a reasonable long term solution of drawing in that company will be imported smoothly, and the last research action would be executed finally.

Figure 3.2  Flow diagram of software implementation
4. Results

Chapter 4 presents the execution of the designed methods. Chapter 4.1 to chapter 4.5 refer to every step of software selection method (chapter 3.1). Chapter 4.6 and 4.7 refer to the suitability assessment and software implementation (chapter 3.2 and 3.3).

4.1 Requirement analysis

The analysis is divided into several aspects. Firstly, functions and features of the software that the company currently use will be judged. The aim is to find what the demands of the company and the shortage of the software are. Then, about the document format requirement, the interface point will be discussed. As another important issue, what the frequent drawing targets are will be introduced next. For concluding all the information, a short list of key features for the company to select the new software will be analyzed in the end.

4.1.1 Current software investment

1. OpenOffice Draw

Mr. Jos de Munck is one of the staff in AquaControl who is responsible for system installation, cabinet and other constructions design and assembly. He uses ‘OpenOffice Draw’ to draw the constructions and electrical schemes. OpenOffice is a free office software set and one of the applications is Draw. In OpenOffice Draw, users draw straight line, curve, arrow, quadrangle, ellipse and other simple shapes, just like using shape function in Microsoft Office Word. Although the application is originally designed for drawing flow diagram or other graphic sketches for planning or communication, Mr. de Munck uses it to draw 3D constructions like holders, and electrical sketches and plane views in cabinet. The difficulties and inconveniences include in three phases. First, all the symbols have to be drawn by basic lines in advance. Second is that it is impossible to define the distance between two objects and to define the dimensions in real figures and unit. The third one is to fix the changed data in title blocks for every page without the function of auto update.

As OpenOffice Draw is a basic graphic sketch software, Mr. de Munck takes much more time to finish the drawing tasks by it rather than by professional drawing software. Besides above inconvenience, Mr. de Munck wondered other possible improvement points for the drawing software. A customized symbol database could be provided to simplify the task of electrical drawings. Up to now, he created a sheet particularly for editing and copying all the symbols. It will be better if the symbols could be saved in database and picked up at any time. Meanwhile, since he usually needs to import the drawings (provided in .dwg and .pdf formats) from other manufacturers, the software can be best to directly read the .dwg files and edit them. Because OpenOffice Draw cannot read the .dwg files, he has to draw all the needed drawings by himself by reading the .pdf files every time. It is worthless to take lots of time on this work.

In all, the information about the software and its usage are listed in the below table.
Table 4.1 Interview record

<table>
<thead>
<tr>
<th>Software</th>
<th>OpenOffice Draw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provided functions</td>
<td>Basic lines drawing, basic shape drawing, Text editing, Table, Chart</td>
</tr>
<tr>
<td>Drawing target</td>
<td>3D construction, electrical schemes</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>Inconvenience</td>
</tr>
<tr>
<td>• Quick start</td>
<td>• Insufficient draw functions (hard to draw symbols)</td>
</tr>
<tr>
<td>• Free</td>
<td>• Could not put driving dimensions on the lines or distance between the objects</td>
</tr>
<tr>
<td>• No complex function</td>
<td>• Manually update the changes in title blocks</td>
</tr>
<tr>
<td>Required improvement</td>
<td>• Customized symbol database</td>
</tr>
<tr>
<td></td>
<td>• .dwg format files import support</td>
</tr>
</tbody>
</table>

After the interview, the software had been tried and invested by the student to check whether there is the possibility to realize the required functions. The results are listed by the functions.

1) Symbol library
   The symbol library could be created in the gallery function. To create a customized gallery, the user could drag the objects into the gallery window and reuse it later.

2) Template
   The template could be created to add a table which will be used as the Title block. The information such as the company address, current page, total pages could be input, which will listed in every page of the document.

3) PDF import
   The PDF drawing documents could be imported to the OpenOffice draw after installing the official extension. The precondition is the PDF is generated by other drawing software that contains vector information. In that way, the drawing will be rendered as same as the original PDF and it is possible to edit or copy the selected drawing.

Existing inconvenience

1) The size of lines or shapes could only be input in real scale. If the user input the width and height of a rectangle to 30mm by 20mm, the rectangle would be printed in 30mm by 20mm. Thus if the real dimension of a part is 400mm by 220mm by 50mm, the user has to decrease the scale by himself when drawing each line of the part.

Table 4.2 Investment record

<table>
<thead>
<tr>
<th>Software</th>
<th>OpenOffice Draw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provided functions</td>
<td>Inconvenience</td>
</tr>
<tr>
<td>• Line drawing</td>
<td>• Scale adjustment</td>
</tr>
<tr>
<td>• Shape drawing</td>
<td></td>
</tr>
<tr>
<td>• Text editing</td>
<td></td>
</tr>
<tr>
<td>• Table insert</td>
<td></td>
</tr>
<tr>
<td>• Master view(template)</td>
<td></td>
</tr>
<tr>
<td>• PDF import</td>
<td></td>
</tr>
<tr>
<td>• Customized gallery (symbol library)</td>
<td></td>
</tr>
</tbody>
</table>
2. AutoCAD 2000

Mr. Rob Schipper is the user of AutoCAD 2000 in that company. Although it is early version of AutoCAD, it has the core functions of professional 2D drawing software, including sufficient lines and shapes choices, layers, easy dimension definition and so on. Mr. Schipper has contacted this software for several years. Although he had few experiences before, up to now he has handled quite amounts of knowledge to operate the common functions.

Currently, he uses this application to draw P&ID schemes mostly and sometimes some mechanical 2D drawings of the installations. The AutoCAD could draw and show more precise mechanical drawings to the manufacturers for producing the customized piping systems or other installations. It is also convenient to communicate with the clients to show the design and ideas.

However, the hardness to express construction in 2D become the communication barriers between Mr. Schipper and the construction manufacturers. The hardness caused not only by the lack of mechanical drawing training, but also by the difficult imagination of three views of complex constructions or piping systems. It is hard to estimate the average time used on one page of the drawings but it really adds unwanted time to think how to express the three-dimensionaled installations in 2D drawings. Another inconvenience happens in designing the components in small space. It will be hard to see the detail in small space when the scale is reduced due to contain the entire installation.

In addition, the document exchange and share inside the company is a problem as well. Mr. Rob Schipper uses AutoCAD 2000 while Mr. Jos de Munck and Mr. Dick Snoek use OpenOffice. They save their drawing files in one server but could not open the files created by the other application. This situation greatly decrease the efficiency to work together and create redundancy of the documents. So in the solution, the drawing documents could be opened and edited by everyone of the company.

Table 4.3 Interview record

<table>
<thead>
<tr>
<th>Software</th>
<th>AutoCAD 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provided functions</td>
<td>sufficient lines and shapes choices, layers, easy dimension definition</td>
</tr>
<tr>
<td>Drawing target</td>
<td>P&amp;ID schemes, mechanical drawings of installations or constructions</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Satisfaction</th>
<th>Inconvenience</th>
<th>Required improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Precise dimensions definition</td>
<td>• Difficulty to build the design in 2D</td>
<td>• The document could be read and edited by everyone</td>
</tr>
<tr>
<td>• Data reuse and recreation</td>
<td>• Designing components in small space</td>
<td></td>
</tr>
<tr>
<td>• Essential 2D drawing functions</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.1.2 Interface points

Interface points represent who the company share files with, how often and in what format (Green Robert, 2006)[6]. In general, AquaControl both receive the drawings from the vendors and deliver the drawings to suppliers or clients. The situation is detailed below:

1) Deliver to the clients

As an engineering company, AquaControl has the need to demonstrate the installations (both in mechanical drawings and in P&ID drawings) to the customers frequently. The company send the pdf version and also hard paper currently, but they have the requirement to share the documents in CAD data (preferably AutoCAD format).
2) Deliver to the suppliers

For manufacturing the installation, they usually have to design and custom the parts or constructions. In that case, they need to deliver the drawings to the supplier for the producing. Up to now, the company send the pdf version. However, there will be discount benefits from the suppliers if the company could provide CAD data because the suppliers will save the time to draw the parts again for CNC (Computer Numerical Control) machining.

The reason why the company just deliver the pdf documents is that, for the OpenOffice draw, the direct output is .odg which is a less popular office document format rather than .pdf and does not contain the CAD data, while for the AutoCAD 2000, the user, Mr. Schipper, does not have sufficient capability to draw professional mechanical drawings. Most of the drawings created by Mr. Schipper are understandable for technical staff but risky if directly used in machining, so it is better to deliver the drawings in pdf format under the consideration of universality and data correction.

4.1.3 Drawing targets

As a water treatment company, water treatment installation/system is the top target of drawing. The crucial targets are that:

1) Large amount of structural components and pipes
   A characteristic of water treatment installation is the large amount of pipes. The water under processes has to go through the pipes to be treated by equipment. Meanwhile, the structural components/constructions are frequently used to fix the pipes. The features and shapes of the elements are simple, but the parameters must be precise in order to connect the pipes correctly.

2) Different kinds of water treatment equipment
   Besides the EDI installations, AquaControl have the business to maintain/improve the existing water treatment system. In this case, they need to replace part of the system to new equipment which will connect the existing pipes. The measurement of new equipment should be precise for the accurate fixation to the existing system. In addition, some components of new equipment, like the door of control panel and the hand wheel of valve, should be good accessible for the later maintenance work.

4.1.4 Key features

Besides the above results, there are other features which were required in the interview with the staff. The information is collected into the table which will be used as the criteria in the software selection. The table are presented in the next page.
4.2 Cost analysis

The cost analysis starts with the list of the cost sorts of the company. In general, the costs are classified by product cost and period cost\(^7\). In product cost, the labor, material, pre-financing cost, machinery, housing rent, electricity and logistics are included. The marketing cost, software/hardware are judged as the period cost.

No matter the product cost or the period cost, the upgrade of 3D software would affect them. The effects would be described in detail.

4.2.1 Cost decrease

1) Material

The 3D modeling solution has the specification of precise dimensions, which would lead to the less possibilities of mistakes. The pre calculation of the amount of material will be more accurate and the material management will be more successful. Also, the situation of the material reorder caused by unexpected design change, so the transport cost will reduced.

Specially, the company usually have the requirement of customized parts. For that kind of materials, manufacturers supply discounted price if the drawing is delivered through CAD format. If the upgrade is done, cost spent on the customized materials will be lower as well.

![Figure 4.1 Flow diagram of material cost](image-url)
2) Labor

The new 3D software of course would decrease the drawing time compared with the former drawing methods. As one of the most important features, the software must be friendly operated, which means the software will increase the efficiency of designing. Meanwhile, the new software keep exploring new features to help the designers fasten the drawing speed. In addition, the predictable part library will have the effect to improve the efficiency. As the result, the time cost in drawing and the corresponding labor cost used in drawing will be decreased.

![Flow diagram of labor cost](image)

3) Marketing

A successful marketing cannot be separated from attractive demonstration. Undoubtedly, the 3D intuitive view of the installation would give the client a persuasive first impression. In result, the possibility to obtain the order would be larger while the market cost will be more effective and beneficial.

Another effect of intuitive view is the decreased design complexity. As same as the friendly operation feature, this will also has a positive influence to the drawing time.

![Flow diagram of marketing cost](image)

4.2.2 Cost increase

The upgrade of new software will increase the cost in the first period. The affected costs include the software expense, hardware expense, and the productivity time caused by the training.

As the benefit of upgrade will influence the company continuously in the future, the one-off investment of software and relevant hardware could provide much more profit for the company.

Compared with the worthy software cost, lost productivity is the true lost (Green Robert, 2006). The amount of time a user tries to learn new software is where real money gets lost, which reflects the importance of right software selection and successful implementation.

4.2.3 Conclusion

Although it is hard to quantify the increased and decreased cost, it is acceptable that the software is worth upgrading for the benefits in aspects. What should be noted is the implementation plan, which influence to what extent the success of upgrade will be.
4.3 Available software

This section could be judged as the preliminary review of the software. The approved ones will be identified in the short-list of trial software and be carefully tested in the next section. Since there is a large amount of CAD software in the market, a simple criteria should be built to quickly select the software that will be reviewed in this section. The structure of the select process could be understood by the below figure.

![Venn diagram of available software](image)

**Figure 4.4  Venn diagram of available software**

After the consideration, the preliminary review software will be chosen among the popular ones and economical ones. The popular ones have been proved to shorten the time to market and cut the costs by big user groups. These software are worthy to be picked into the preliminary review software. As a small company, the budget also has to be seriously considered. Since the requirements to the software are not so high for the company, it has a large possibility that the economical software could fit the demands. So the group of economical software should be paid attention to as well.

In popular software group, AutoCAD 2014, Inventor LT 2014, AutoCAD electrical/AutoCAD P&ID, Solidworks standard 2013, and PTC Creo were reviewed, while in economical group, FreeCAD 0.13, SketchUp 2013, ZW3D 2014, Rhinoceros 5, BricsCAD were grasped. As the preliminary selection, only the core requirements, which are 3D modeling function, ease of use, and 2D drawing function, were investigated. The software which meet the core requirements would be approved. Otherwise, they would be taken away.

After the preliminary review, three software were left. The result was concluded in a table, and the detail of the process was recorded in the appendix I.
<table>
<thead>
<tr>
<th>No.</th>
<th>Software</th>
<th>Result</th>
<th>Remarking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>AutoCAD 2014</td>
<td>Failed</td>
<td>overly complicated 3D modeling function</td>
</tr>
<tr>
<td>2.</td>
<td>Inventor LT 2014</td>
<td>Approved</td>
<td>Ease to use 3D function</td>
</tr>
<tr>
<td>3.</td>
<td>AutoCAD electrical/ AutoCAD P&amp;ID</td>
<td>Failed</td>
<td>No 3D function</td>
</tr>
<tr>
<td>4.</td>
<td>Solidworks Standard 2013</td>
<td>Approved</td>
<td>Extensive 3D modeling functions</td>
</tr>
<tr>
<td>5.</td>
<td>PTC Treo</td>
<td>Failed</td>
<td>Install failure</td>
</tr>
<tr>
<td>6.</td>
<td>FreeCAD 0.13</td>
<td>Failed</td>
<td>Hard to use, Low stability, lack of support</td>
</tr>
<tr>
<td>7.</td>
<td>SketchUp 2013</td>
<td>Failed</td>
<td>Lack of mechanical drawing features</td>
</tr>
<tr>
<td>8.</td>
<td>ZW3D 2014</td>
<td>Approved</td>
<td>Enough (seem) functions and attractive price</td>
</tr>
<tr>
<td>9.</td>
<td>Rhinoceros 5</td>
<td>Failed</td>
<td>Unsuitable modeling method, hard to re-modify the sketch</td>
</tr>
<tr>
<td>10.</td>
<td>BricsCAD</td>
<td>Failed</td>
<td>hard-to-use interface design</td>
</tr>
</tbody>
</table>

The approved software are Solidworks, Inventor LT, and ZW3D. All of them fit the core requirements of the company and will be tested carefully in the next section to judge which one is the most suitable software to the company.

4.4 Software trial

After looking the available software up, three software were approved in the primary selection. In this section, the three software will be judged thoroughly according to every factor of requirements and the score of the software for every factor will be concluded after the trial.

4.4.1 ZW3D 2014

ZW3D is a typical mechanical 3D CAD software which uses the parametric and feature-based modeling method. Under this method, engineering solid models are built mostly with sketcher-based features, and the 2-D sketches are swept along a path to become 3-D. These may be cuts, or extrusions for example.[8] Also, ZW3D supports assembly modeling method. An assembly model incorporates references to individual part models that comprise the product (Donald E. Lacourse, 1995).[9]

1) Version comparison

ZW3D 2014 provides various versions for different requirements. In this case, Standard version is powerful enough for the company. The upper version, premium version, provides core cavity creation, mold base library, cooling channels, slider, insert and electrodes creation, which are all unnecessary functions for the company. While in the lower and also the lowest version, lite version, the animation demonstration and real-view are the absent features which may be valuable to obtain. The choosing of version will be processed if ZW3D is selected.

2) 3D modeling functions

ZW3D provides plenty of functions in the ribbon interface. For part design, the shape ribbon provides common functions to build the features. For assembly, sufficient functions are also clearly listed.
3) Training materials
ZW3D provides aspects of tutorial for the beginner. For every function, a pop-up window, which introduce the function, will appear if the mouse stop on the corresponding button.

In the software, the training column provides the training manual for all the functions, while the special Show-n-Tell column provides unique training environments where the user is guided through the process of constructing and documenting real parts using basic ZW3D commands. The official account in YouTube provides abundant video tutorials for all the functions in English [10]. The example figures of ZW3D training materials are shown in Appendix II.

4) Supported formats
The ZW3D could directly edit 3D models from other popular CAD software while it can export STEP, AutoCAD format and CATIA format. The supported file extensions are totally sufficient for the company. The details are listed in figure 4.8.

As an experiment, a P&ID drawing (.dwg file) which was designed by the staff was imported to ZW3D. The experiment succeeded and the imported drawing works well. All the layers could be switched the same as in the original software.
5) Part library
   The part library function is provided in two sub sections. One is the build-in part library, whose parts are already provided in the library, but the cover of the library is not so wide. The other one is the customized part table, whose parts could also be imported in the future.

   \[\text{Figure 4.9} \text{ Part Library/Table for ZW3D}\]

   The defect of the part table is that the changeable parameters is limited to two per part. For example, a block, which is one of the simplest part, has the parameters of length, width and height, while the changeable ones are either two ones. This defect makes this function more or less unworthy to customize the part table.

6) Mechanical drawings
   As mechanical CAD software, the ZW3D provide sufficient functions of mechanical drawings. It can transfer the 3D modeling to mechanical drawings and label the dimensions. Meanwhile, the 2D drawing could also be sketched in the sheets.

   For P&ID and electrical scheme, the customized symbol library is extremely easy and useful. Select part of or the entire drawing sheet as a symbol, assign it a name, an insertion point, and save it for later use. The picking up is a convenient process as well. All the symbols have their names and the previews.

   Another convenient feature of scheme drawing is the grid. The ZW3D provides grid in the sheet interface, which accurately direct the horizontal and vertical lines.

   \[\text{Figure 4.10} \text{ Grid feature for ZW3D}\]

7) Measurement
   The measurement function is provided and sufficient. It is easy to measure the distance between two different parts for understanding the total length or width of the installation (assembly).

   \[\text{Figure 4.11} \text{ Measurement function in ZW3D}\]

8) Vendor support
   The official vendor of ZW3D in The Netherlands is 4C Creative Cad Cam Consultants. During the trial, conversations about the technical problems, expenses and suitability are proceeded. All the questions have
been answered and solved satisfactorily, showing that this software seller has the capability to support the company about the software.

9) Expenses
   The ZW3D standard is €2500, while the lite version is only €800. The manufacturer provides network licenses by soft-key without extra expense. The reasonable price is the largest attraction of this software, especially for the added network licenses service.

10) Specialties
   The ZW3D provides convenient hotkeys and shortcuts to fasten the operating speed, especially the unique usage of mouse middle button, which is the most special specification of the software. In addition, the software supports selecting the axes as the mirror line directly. Users do not have to draw the extra reference line.

11) Weaknesses
   There are still several disadvantages in the ZW3D. First, all the functions are provided while the user may not find it at first. The below figure shows the interface that the user right clicked a solid in order to change the feature parameter. There are two menus appeared and the correct button is the first one of the smaller menu. It is hard to recognize and understand why this icon means the modification.

![Figure 4.11 A right click menu of ZW3D](image)

Another point is the popularity. Since it is not a popular software, it is hard to find help or solutions on the Internet if the user meets problems which could be solved by the official help manual. For the same reason, the resources of standard parts or other models are limited as well.

4.4.2 Solidworks 2014

Solidworks is a famous 3D CAD software, which has sold over 1.5 million licenses worldwide. Its user base ranges from individuals to large corporations, and covers a very wide cross-section of manufacturing market segments. SolidWorks is a Parasolid-based solid modeler, and utilizes a parametric feature-based approach to create models and assemblies as well.\[11\] Its powerful performance and efficient approach led it to software trial. In the coming careful test, it will be judged corresponding to the requirements.

1) Version comparison
   Solidworks 3D CAD software is divided into three versions, which are Standard, Professional and Premium. The standard version contain the function of creation of parts, assemblies and 2D drawings. Application-specific tools for sheet metal, weldments, surfacing, and mold tool and die are also provided.\[12\] The major helpful
benefits of Professional version are CAD library, Advanced CAD file import, and photorealistic rendering. The extra functions of Premium version are over the requirements, so it will not be considered.

2) 3D modeling functions
As mentioned in preliminary review, Solidworks provides plenty of functions of 3D features and 2D sketches, and the capability of assembly. It utilizes feature-based parametric approach, which is easy to understand and easy to learn. By this approach, users design the solid in the loops of creating parametric sketches and applying it with the features. Although the approach is the same in all selected software, their specialties are different.

3) Training material
Solidworks provides extensive build-in tutorials. Through the tutorial, users could learn the software step by step and the tutorial updates followed by the import of new functions (for example, from v2013 to v2014).

As shown in the figure 4.12, the tutorials are arranged to several columns reasonably according to the skill levels. All the designed functions are infused in different tutorials. The non-experienced beginner could grasp elementary knowledge and skills conveniently and independently through it.

Not only all mentioned contents, but also the human-based design enhanced the advantage of this official tutorial. All the function buttons appeared in the tutorial, which are asked to be clicked, are clickable directly in the tutorial and will link to the position of buttons in the toolbar. Users do not have to find it by themselves.

![All SolidWorks Tutorials](image)

**Figure 4.12 Tutorial contents of SW**

![Sketching the Base](image)

**Figure 4.13 Tutorial specialty**

4) Supported formats
SolidWorks provides the build-in translators to convert incoming CAD data into SolidWorks 3D CAD format or to export SolidWorks data to other CAD products. Most of the popular 3D CAD software formats are supported to import, like Inventor, CATIA, DWG file, Pro/engineering, Rhino, SolidEdge and STEP file. The detail of supported import and export formats has been attached in the Appendix II.
As introduced in the trial of ZW3D, a DWG file import experiment has been done. The provided P&ID drawing succeeded to be imported in the Solidworks as well.

5) Part library
The part library function is called “Toolbox” in Solidworks, which is the special function provided in Professional and Premium version. The Toolbox is a huge database that contains over one million standard fasteners and components, including bearings, bolts and screws, keys, nuts, O-rings, pins, washers and so on. All the components are sorted by different standards like ANSI, DIN, and ISO. Users can easily find what they want and drag them into the assembly. This function is another advantage of Solidworks.

6) Mechanical drawings
Solidworks provides variety of functions of annotation in the mechanical drawings to help the user explain the drawing professionally and clearly.

![Annotation ribbon of Solidworks](image1)

Figure 4.14 Annotation ribbon of Solidworks

Meanwhile, users could import different kinds of tables into their drawings, like Table of Materials.

![Table function of Solidworks](image2)

Figure 4.15 Table function of Solidworks

7) Measurement
As a mechanical drawing software, Solidworks provides measurement function. A specialty of this function is the point to point mode, which helps the user to measure the delta x, y, z distance correspondingly. Sometimes, the demands to measure delta distance in axes are existing.

![Measurement specialty of Solidworks](image3)

Figure 4.16 Measurement specialty of Solidworks
8) Vendor support

One of the official vendor of Solidworks in The Netherlands is CAD2M. Aquacontrol contacted them and the seller, who is responsible for communicating to AquaControl, is enthusiastic and active. Video demonstrations and private meeting were proposed by the seller. He also replied the questions about the usability and feasibility of the software. From the experiences, it could be concluded that the vendor is confident to the software and training or support are extensive, while the response usually takes a few days and the replies sometimes didn’t solve the questions.

9) Expenses

Opposite to ZW3D, expense is a barrier to choose Solidworks. The Standard version, which is the cheapest one, costs € 6000. The Professional version will spend € 7500. Meanwhile, the network license access will be charged independently. It will be a huge cost for AquaControl if it is selected.

10) Specialties

An impressing detail design of Solidworks is the alignment design when putting the dimension annotation in the drawings. An example is explained below.

![Auto alignment feature in Solidworks](image)

The second dimension annotation will be automatically aligned to the first one if they are close. This design help to make clear and neat drawings.

11) Weaknesses

During using the sketch function, sometimes it is hard to constrain the sketch into well-defined status, especially after the trim. The skill that analyzes what constraints is lacking, has to be trained and takes a long time to be proficient.

4.4.3 Inventor LT 2014

Inventor is another 3D mechanical CAD software, which is developed by Autodesk since 1999. It uses ShapeManager modeling kernel and is based on feature-based parametric modeling method. It is the main rival of Solidworks in the market.

1) Version comparison

Inventor LT is the economical version compared with Standard one, which is designed to fit the primary requirement of 3D modeling in small size companies. It retains the core functions of Inventor like part-level parametric modeling, multi CAD translation capabilities, automated DWG drawing views, and other CAD capabilities\[13\]. Meanwhile, some valuable functions are removed to decrease the sell price, like large assembly design, sheet metal design, and assembly collision and interference detection. The LT version is selected
instead of standard one because both the price and performance of standard version are similar to Solidworks Standard, which has been proven to be competent and sufficient to the company. In this case, Inventor LT is more attractive and competent considering its price.

2) 3D modeling functions
As shown in preliminary review, common 3D modeling features are provided in Inventor, which are similar in feature-based parametric modeling software. Users could choose different features and put the sketches to them.

3) Assembly function
The largest disadvantage of LT version is the lack of assembly function, that users can only make models in part-level. However, Inventor LT has a capability called multi-solid part, which means the part consists from several sub-parts. It is the only indirect path to accomplish the task of assembly.

To build the multi-solid part, all other sub-parts will be imported into the base sub-part by Derive function. Compared with assembly function, the imported sub-part could not be moved by dragging or setting relationships (also called mates). Instead, the movements include offset in xyz, offset in defined direction, and rotation about line. All the movements of sub-parts have to be ordered in these three ways.

The progress to connect two sub-parts together is shown in Appendix IV. In the example, a Tee pipe and a reducer were created in advance and they are ready to be connected together.

It is obviously that using such an indirect method to assembly is inconvenient and inefficient. If the designer doesn’t remember all the dimensions of sub-parts, he has to measure plenty of distances before ordering the movements. In addition, many of the distances have to be measured after the creation of reference axes.

Meanwhile, it will increase the risks in precise parameters. Since the sub-parts don’t have relationships with each other, the interference will not be alerted and also be hard to detect. However, the errors will be accumulated to a large problem because precise dimension is one of the core requirement of the company.

4) Training materials
Similar to Solidworks, Inventor provides tutorials in its help documents, but the amount of lessons is less than its rival. Thus, most of the topics are related to basic operations. In addition, the lessons are filled with lots of text, which may decrease the motivation of readers.

Figure 4.18  Tutorials in Inventor
5) Supported formats
As a software developed by Autodesk, Inventor has the remarkable capability in importing or exporting the DWG files. The experiment to test it was easily approved by Inventor. All the layers and lines are same as the original. Meanwhile, it is designed to work with common 3D modeling files. The detail of supported formats could be grasped in the below table.

<table>
<thead>
<tr>
<th>Supported Import file formats</th>
<th>Supported export file formats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autodesk Inventor Files (* .lnx, .ipt, .ide)</td>
<td>AutoCAD DWG Files (* .dwg)</td>
</tr>
<tr>
<td>Autodesk Inventor Parts (* .ipt)</td>
<td>CATIA V5 Part Files (* .CATPart)</td>
</tr>
<tr>
<td>Autodesk Inventor Journals (* .jdr)</td>
<td>CATIA V5 Files (* .CATProduct, * .CATProduct * .cga)</td>
</tr>
<tr>
<td>Alias Files (* .sia)</td>
<td>IGES Files (* .igs, * .iges)</td>
</tr>
<tr>
<td>AutoCAD DS Files (* .dxf)</td>
<td>JT Files (* .jts)</td>
</tr>
<tr>
<td>CATIA V4 Files (* .model, *.wrd, *.wrl, *.xsi, *.dxf)</td>
<td>Parasolid Binary Files (* .x_b)</td>
</tr>
<tr>
<td>CATIA V5 Files (* .CATPart, * .CATProduct, * .cga)</td>
<td>Parasolid Text Files (* .x_t)</td>
</tr>
<tr>
<td>DXF Files (* .dxf)</td>
<td>Pro/ENGINEER Granite Files (* .g)</td>
</tr>
<tr>
<td>IGES Files (* .igs, * .iges)</td>
<td>Pro/ENGINEER Neutral Files (* .nas)</td>
</tr>
<tr>
<td>JT Files (* .jts)</td>
<td>CAT Files (* .cat)</td>
</tr>
<tr>
<td>IRIS Files (* .prt)</td>
<td>STEP Files (* .stl, * .step)</td>
</tr>
<tr>
<td>Parasolid Binary Files (* .x_b)</td>
<td>STL Files (* .stl)</td>
</tr>
<tr>
<td>Parasolid Text Files (* .x_t)</td>
<td>IGES Files (* .iges)</td>
</tr>
<tr>
<td>Pro/ENGINEER Granite Files (* .g)</td>
<td>SOLFiles (* .sols)</td>
</tr>
<tr>
<td>Pro/ENGINEER Neutral Files (* .nas)</td>
<td>Parasolid Text Files (* .x_t)</td>
</tr>
<tr>
<td>Parasolid Binary Files (* .x_b)</td>
<td>Parasolid Binary Files (* .x_b)</td>
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</tr>
<tr>
<td>Pro/ENGINEER Neutral Files (* .nas)</td>
<td>Parasolid Text Files (* .x_t)</td>
</tr>
</tbody>
</table>

6) Part library
The customized part library function is one of the specialties of Inventor, which called iPart. The iPart function is designed to create a series parts which has same features and different dimensions, like pipes in different diameters. First, the user build one part in that series, then select iPart function. In the dialogue window, the user can select the parameters that will be changed in series and input the figures. Inventor will generate a table and the user could choose the part in required sizes in the later use.

This function could exploit the advantage to the full in the parts-in-series demands.

Figure 4.19  iPart function in Inventor

7) Measurement
As a basic function of 3D modeling software, measurement is added in Inventor as shown in figure 4.20. Different choices are designed for different measure requirements.

Figure 4.20  Measure function in Inventor
8) Mechanical drawings
Inventor provides the capability of 3D to 2D transfer function. Users could select different views and insert section and detail views. Also, sketches could be finished in mechanical drawing. A defect of Inventor LT is that, since the assembly function has been removed, the Bill Of Material function is not existed because the model is just one part. The only choice is to build a blank table and type the text. This disadvantage decrease the performance of Inventor again.

9) Expenses
The Inventor LT sells in two kinds of packages. First is the stand-alone package, whose price is € 1325. Second is the Inventor LT suite, which is bundled with AutoCAD LT. AutoCAD LT is also the limited version of AutoCAD, whose 3D capability is removed. The Inventor LT suite costs € 1825. It is the lowest price in the three selected software. Moreover, the LT version doesn’t support network access, so the software could only be used in one computer. However, three of the company staff have the demands to use the software. The network licenses choice will be more convenient.

*Network license access explanation:*

A network license supports the use of the software up to a maximum number of users or “seats”, who are connected to a server network. The products can be installed on as many computers as desired; however, at any one time, can only run on the maximum number of computers for which licenses have been purchased. Because you can install the products on more systems than the number of licenses purchased, you get true floating licenses across your entire organization.[14]

10) Specialties
The right-click menu of Inventor is designed friendly. It remembers the last order for the user. Moreover, users could select the common functions conveniently from the right-click menu, as shown in the below figure.

![Right-click menu in Inventor](image)

**Figure 4.21** Right-click menu in Inventor

11) Weaknesses
Normally, the user can rotate the models in 3D modeling software by holding the central button of the mouse and then dragging. In Inventor, not only the central button, but also the Shift key have to be held if the user wish to realize this common function. Then the Shift key will be pressed frequently. Although it will not affect the efficiency, this detail design is not so user-friendly.
4.4.4 Observe test

In order to increase the reliability of the trial result, an observe test is imported. The observe test is divided into two parts. First, a demonstration to make the same model in three software will be introduced by the student and observed by company staff. Second, a simple drawing task will be arranged for the staff to try it themselves. The company staff can get a sense of how the software operate and which one is easier to operate through the test. Finally, scores of three software will be marked by staff and be taken into consideration in the score matrix.

<table>
<thead>
<tr>
<th>Base box</th>
<th>Cover Box</th>
<th>Button</th>
<th>Screw</th>
<th>Assembly</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Base box" /></td>
<td><img src="image2.png" alt="Cover Box" /></td>
<td><img src="image3.png" alt="Button" /></td>
<td><img src="image4.png" alt="Screw" /></td>
<td><img src="image5.png" alt="Assembly" /></td>
</tr>
</tbody>
</table>

*Figure 4.22 Demonstration models*

The figures show the models designed for demonstration. Since the models have to be built in three software and the explanation will take quite amount of time, the models are designed to contain the most common but simple features and functions, including extrude base, extrude cut, hole, thread, loft, fillet, chamfer, and mirror, trim, constraint. For ZW3D and Solidworks, the assembly usage was demonstrated, while for Inventor, the multi-solid part method was shown.

After the observation, the staff commended that they felt Solidworks is more professional but more complex than other two. The time spent on the constraints was longer, which made them doubt about the ease of use.

During the demonstration of sub-part movement in Inventor, the staff revealed their worry on its capability of large system installation. The difficulty may be multiplied when the scale of installation expands.

After the demonstration of three software, ZW3D left a deep impression for its balanced performance and economical price on the company staff. Mr. Schipper succeeded to build a model of Tee pipe by ZW3D under the help of student.

In the end, the most satisfying software among the three options was ZW3D in the staff’s opinion. No complicated usage and no apparent disadvantages were their remark on it.

4.5 Decision support matrix

After the whole trial processes of three software, a method called factor rating method will be imported to make the final decision, which uses decision support matrix to proceed.

The factors, which were developed based on the software requirement in the previous section and the observe test, will assigned the weight. Each of the potential software packages was given a score for each of the factors. The scores will then be multiplied by the weight, and the result total for each package will be compared and concluded to final decision.
4.5.1 Result

<table>
<thead>
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<th>Requirements</th>
<th>Weight score [1 - 5]</th>
<th>Wei.score [0 - 10]</th>
<th>Score [0 - 10]</th>
<th>Wei.score [0 - 10]</th>
<th>Score [0 - 10]</th>
<th>Wei.score [0 - 10]</th>
</tr>
</thead>
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<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
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<td>Essential Reasonable price</td>
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<td>9</td>
<td>36</td>
<td>4.5</td>
<td>18</td>
<td>7.5</td>
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<td>Usage Ease to use</td>
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<tr>
<td>Usage Supported file formats</td>
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<td>24</td>
<td>8</td>
<td>24</td>
<td>7</td>
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<td>15</td>
<td>7</td>
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<td>21</td>
</tr>
<tr>
<td>Support Tutorial/Help file</td>
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<td>6</td>
<td>24</td>
<td>8</td>
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<td>24</td>
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<tr>
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<td>7</td>
<td>14</td>
<td>7</td>
<td>14</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Support Vendor support</td>
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<td>Additional value Network/Multiple license access</td>
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<td>0</td>
<td>6</td>
<td>24</td>
<td>9</td>
<td>36</td>
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<tr>
<td>Additional value Parts library</td>
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<td>14</td>
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<td>16</td>
<td>5</td>
<td>10</td>
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<td>Observe test Impression from staff</td>
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<td>25</td>
<td>3</td>
<td>15</td>
<td>8</td>
<td>40</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>309</strong></td>
</tr>
</tbody>
</table>

The result shows that ZW3D got the highest score (369.5). According to the result, ZW3D is the most suitable 3D modeling software to reduce the cost and meet the demands of the company. It provides required functions, attractive price, and professional reseller support. It is trusted that the company could benefit a lot from this 3D modeling software.

4.6 EDI stack model demonstration

Even though ZW3D has the highest score, unexpected issues are still possible in real projects. Hence, to evaluate the fitness of the software, in the case, an EDI stack will be selected to be modeled in that 3D software.

The reason to choose EDI stack is that it is one of the key subject of the drawing, it is fairly complex and it is expected that in the future, designers will work on EDI installations. EDI installations are used to produce ultra-pure water. The photo on the cover is an assembled EDI installation.

The 2D mechanical drawing and the real machine were provided by the company. The 3D models would be designed according to the dimensions from the 2D drawings in the original idea. However, except the key
parameters which effect the system assembly, not many dimensions are mentioned in the drawing. Another idea had to be created to fix the changed situation.

After excluding the measurement method, the final solution is to transfer the .pdf file to .dwg file, import the .dwg file into the ZW3D, and copy the required drawing to the sketches. This simple 2D to 3D solution made modeling become possible.

After approximately two and a half days, the models were completed, which proved that the ZW3D has the capability and suitability to work in this industry from the practical aspect. The finished models are demonstrated here.

*Figure 4.23  Auxiliary view of EDI stack model*  
*Figure 4.24  Top view of EDI model*  
*Figure 4.25  Side view of EDI model*  
*Figure 4.26  Front view of EDI model*
4.7 Software Implementation plan

Implementation deals with the transfer of the new software in the company. The aim is to realize the independent operation of ZW3D by the company staff within their demands. The implementation will be prepared in the plan.

The implementation is divided to phases because it contains many procedures. Each section below corresponds to one phase.

4.7.1 1st implementation

The first phase will deal with the software and hardware purchase.

1) The official reseller of ZW3D in The Netherlands is Creative Cad Cam Consultants. The contact information is:

   Creative Cad Cam Consultants
   Meerstraat 79
   7815 XB Emmen
   The Netherlands
   T +31(0) 591 377 442
   F +31(0) 591 377 380
   M +31(0) 6 101 430 60

   Mister Edwin Rappard is the sales manager who is responsible to communicate with the company. AquaControl could contact him to purchase the software. The price of ZW3D standard version is € 2500 per license. There is no extra cost for network licenses.

2) Since the new computer has been taken into account to operate the new software smoothly, the hardware requirement should be prepared in order to buy the suitable computer, as shown below. The requirement is collected from the official website of ZW3D.

   Processor: Intel Core 2 Duo @2GHz or above
   RAM: Recommended configuration: 4G or above
   Video: nVIDIA Quadro FX 580 @ 512MB or above, or equivalent AMD Graphic card
   Recommended configuration: 1280 x 1024 or above

   In the detail situation, it is recommended to communicate with the software reseller if the new computer is required. The official requirement may be not competent enough to make the modeling (especially assembly). A simple method is to test the performance is to open the assembled EDI stack on the test computer, and rotate it. If the movement of the model doesn’t delay, the computer will be competent.

4.7.2 2nd implementation

In the second phase, the staff of AquaControl will start to learn how to use the software.

1) Customized training guide

   The training is divided into two parts, the first is the official video tutorials and the second part is the tricks and tips summarized by the student.
The official video tutorials are the most valuable and effective training materials of ZW3D. Video is the most understandable teaching method except the real teacher and the contents of training videos provided by ZW3D are designed step by step (which means they are well structured) and example-oriented. Meanwhile, the English-speaking commentator pronounces clearly.

Through watching the videos, learners could grasp experiences of most functions and skills in 2D sketches, 3D modeling and 2D drawings of ZW3D. Using the official tutorials instead of editing the original manuals could avoid missing knowledge caused by the student’s knowledge blind side.

Besides the videos, the tricks and tips that have been experienced by the student can save the twists and turns for the staff. All the tricks and tips are recorded in the Appendix V.

2) Training schedule

The amount of time a user flounders while trying to learn new software is where real money gets lost. Thus a reasonable time schedule should be designed in order to minimize the lost productivity.

A decentralized time schedule will make the large blocks of time become fragments, which are disadvantageous to the staff because their work usually will take several hours.

Instead, a concentrated 2 hours or 2.5 hours which will be used to learn software per day is the most suitable method for them. The new knowledge should be limited per day, otherwise the efficiency will be decreased and the bored motion will be produced. Thus 2 hours is set to obtain enough knowledge and maintain the enthusiasm. They can decide the start time according to the business schedule in that day. In the 2 hours, they should focus on the learning.

<table>
<thead>
<tr>
<th>Table 4.7 Training schedule</th>
</tr>
</thead>
</table>

| Day 1: | Day 5: |
| Training contents: | Training contents: |
| a) First three videos in “Learning 3D design in 3 hours” [16]. | a) Review the lessons yesterday and Practice to draw 2D sheet. |
| (I. Basic operation II. Sketch III. 3D modeling) | Day 6: |
| b) Self-practice | Training contents: |
| Training contents: | b) Self-practice |
| a) Other three videos in “Learning 3D design in 3 hours”. (IV. Advanced 3D modeling V. Convert 2D data to 3D models VI. Work with 3D and 2D data) | Day 7: |
| b) Self-practice | b) Self-practice |
| Day 3: | Day 8: |
| Training contents: | Training contents: |
| a) Videos in “ZW3D assembly” [17]. | a) Video in “ZW3D 2014 new features” [21]. |
| b) Practice model: the model in observe test | b) Self-practice |
| Day 4: | Day 9: |
| Training contents: | Training contents: |
| a) Videos in “ZW3D Tutorials of 2D sheet” [18] from 1 to 7. | a) Video in “ZW3D 2013 Animation introduction” [22]. |
3) Hard points communication and records

The difficult points could be noted by several method, like text, screen-shot, or screen recording and be communicated with the reseller of ZW3D. The reseller provides helpdesk for training and technical problems solving especially the user has the targeted question. The build-in help document and manual provides the helps as well.

![Help solutions in ZW3D](image)

**Figure 4.27** Help solutions in ZW3D

4) Drawing training on water treatment machines and installations

After learning the basic operation skills from the video, the practice on real installation will be the best method to apply the knowledge. It is usual that the difficulties happens, while the experiences to solve them are the only way to acquire more skills and become more familiar with the software.

4.7.3 Final implementation

Prediction on future requirement updates

As one of the required features, rendering will make the model more vivid. ZW3D provides photorealistic rendering function and the user can customize the material, lighting, background, and camera position. The ZW3D rendering engine is Artisan, whose effect can be grasped from the official brochure.[23]

However, this functions need additional skills on light settings, color and material settings, which will depend on personal talent more or less. Thus, the training about rendering will be arranged at last. This is also because the skill has rare relationship with the modeling skills.

The rendering plugin provides plenty of choices and the interface is simple to operate as shown in the figure and related video. The rendering function will not arrange the training materials because the effect depends more on the color collocation than operation skills.

![Rendering interface in ZW3D](image)

**Figure 4.28** Rendering interface in ZW3D
5. Conclusion and recommendation

5.1 Conclusion

In this thesis, the central question is which 3D modeling software is most suitable to reduce the cost and meet the demands of AquaControl.

1. After the careful research and trial, it can be concluded that for AquaControl, the 3D modeling software ZW3D is the best choice.

   All the demands of AquaControl, for example the ease of use, rich functions, support on CAD file import and export, are fulfilled by ZW3D. Meanwhile, the economical price maximises the benefits of cost.

2. The result also proved that it is necessary to have a systematical analysis on the requirement and it is worth following the software selection method.

   Without the research on the company requirement, Solidworks might well be selected because of its popularity and professional functions. Without the careful trial, Inventor LT was likely to be chosen for the attractive price and user-friendly interface. No one foresaw ZW3D, a little-known software, would be the final result. And now, we are all satisfied with the choice. It indeed meets the demands and has a reasonable price.

3. In the software trial, the most important issue is to ensure the reliability of the result.

   In the article Quantitative methods for software selection and evaluation (Bandor, 2006)\textsuperscript{[24]}, it is recommended to use a selection team in the software selection because it virtually eliminates a single-person perspective or bias. In this assignment, because of the scale of company and the budget, it is unpractical to import a team. Alternatively, other measures were executed.

   1) Decision support matrix:

      It was indicated that decision support matrix is the most useful tool in the software selection workflow. It uses the factor rating method and its result could not be predicted until the calculation on all the software.

   2) Observe test

      In the observe test, the non-experienced staff were invited to attend a demonstration and to try the software. Their opinions were added as an important factor in the decision support matrix. This design decreased the bias, and increased the reliability again, so it is really suitable if the amount of researchers is limited.

4. No software is suitable for everyone. The one fits you is the one belongs to you.

   Since the CAD market is huge, the amount of CAD software increases continuously. The popular software are definitely valuable to have a try, while they might not be the most suitable software for all situations. It is worthy to give a chance to the emerging software.
5.2 Recommendation

When looking for new modeling software, every step in the workflow of software selection method is essential to conclude the best result. It is recommended to follow the method.

1) Requirement analysis

Clearly understanding what you need is the foundation of 2D to 3D upgrade. If the company upgrades because they think it is the right thing to do, they will simply waste money. According the result of the analysis, it would be clear both for the software reseller and yourself that whether you really need to upgrade and what software fits optimally in your design processes.

2) Cost analysis

The cost for 3D modeling software is expensive in most cases. The cost analysis helps you to understand to what extent the benefit of new software offsets the extra cost. It is the other aspect to judge the value of 3D software upgrade.

3) Available software

Since there are a large amount of CAD software in the market, it is better to have a deep trial for only three or four software after a quick preliminary review on available software.

4) Software trial

In the software trial, every feature which has been concluded in the requirement analysis should be tested and scored for each software. The score helps to get the conclusion by decision support matrix and the matrix is useful and reliable because the result could not be concluded before the calculation on all the software.

Upgrade to 3D modeling software will cost money and productivity, while it is worth to follow the development of CAD. The continuous updates of software increase the efficiency of design and provide more convenient tools compared with old ones. Meanwhile, growth in quantity of software make the choice become various and complex. As recorded in the conclusion, the most important criteria is to meet the design needs. No software is the best software for everyone, the fit one will be the best one.

For ZW3D, a strong interest is aroused to further explore it. ZW3D premium provides many extra professional functions, like FEA, Reverse engineering, CAM and so on. The knowledge of these professional functions is wanted. In addition, the possible improvement for the software and the reason why it is little-known could also be researched in the future.
Appendix I: Preliminary review of available software

Popular software

1. AutoCAD 2014

The software taken into consideration firstly is AutoCAD. AutoCAD is a software application for 2D and 3D computer-aided design (CAD) and drafting. AutoCAD is used across a range of industries, including architects, project managers and engineers, among other professions. AutoCAD has included support for .dwg, a format developed and promoted by Autodesk, for publishing CAD data. The newest version is AutoCAD 2014, and the price is €4775 ex. VAT per license.

The user can choose 2D drafting or 3D modeling in workspace bar on the top of interface of AutoCAD. In each kind of workspace, AutoCAD provides specific functions and sub functions to draw the models, as you can see in the figure I.2. The various functions are enclosed with the explanations which will be indicated when the user stop the mouse on the function button. Although abundant functions are presented on the interface and the layout is clear and easy to use and understand, the layers structure, which is one of the famous features of AutoCAD, is hard to manage for beginner. Maybe it is convenient to manage the drawings when the sketch is complicated, it is not useful when drawing 3D modeling.

In addition, even though AutoCAD provides integrated 3D modeling function, the user should draw completed 2D drawing at first and transfer it to 3D modeling. This procedure may need more time and skills to draw 3D modeling rather than creating 3D modeling directly from 2D sketch, like SketchUp. The figure I.3 will show the example.
The users among the Internet also commended that AutoCAD specializes in 2D while it has 3D functions.\[^{27}\][\(^{28}\)] Under the consideration of the disadvantage of inconvenient 3D modeling, it is not wise to select it as the trial software.

<table>
<thead>
<tr>
<th>Result</th>
<th>Remarkings</th>
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<tbody>
<tr>
<td>Failed</td>
<td>overly complicated 3D modeling function</td>
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</table>

2. Autodesk Inventor LT

Autodesk Inventor is a 3D mechanical CAD design software for creating 3D digital prototypes used in the design, visualization and simulation of products.

Compared with AutoCAD, Inventor is more specifically designed for mechanical drawing. It has a lot of intuitive tools to help make drawings easier and faster to create (mechanical drawings). In normal use, the user firstly create the 2D sketch (by control the length of points), and then add a 3D specification to it. The usage in Inventor is more intuitive and easier for mechanical drawing, as it is its goal.

With AutoCAD, the user can do many types of different drawings such as: Architectural, Civil, Mechanical, etc.\[^{29}\]. Because it is not geared towards one discipline, it can be more difficult and time consuming to create the drawings.

Inventor is designed to create Mechanical drawings.
Other features for Inventor are attractive as well. Inventor is supported to save .DWG file, which is the drawing file format widely used and to import and export third-party 3D CAD data, also to reuse the AutoCAD 2D data.

The Autodesk inventor has three versions: LT (limited technique), standard, and professional, designed for different requirements. LT version is the basic one. Users could buy standard-alone Inventor LT for €1325 or Inventor LT & AutoCAD LT suite for €1825. Inventor standard sells €5000, while professional sells for €8000. The detail difference between three versions could be seen on the website of Autodesk. However, the most significant disadvantage of Inventor LT is that it lacks the functions of assembly.

As a typical 3D mechanical CAD Software, Inventor LT has the attractive price while limited functions. It is decided to put it into the short-list to test that whether the limitation will affect the design or not.

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<thead>
<tr>
<th>Result</th>
<th>Remarking</th>
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<tbody>
<tr>
<td>Approved</td>
<td>Ease to use 3D function</td>
</tr>
</tbody>
</table>

3. AutoCAD electrical/ AutoCAD P&ID

Plenty of professional functions on electrical scheme drawing or instrument symbol libraries are designed in AutoCAD electrical[31] or AutoCAD P&ID[32]. They have been taken into account at first because of the need to draw electrical scheme and P&ID scheme in the company. However, during the test, the function of 3D drawing could not be found and there is also no data about 3D drawing in AutoCAD electrical or AutoCAD P&ID on the internet and their help documents. Considering its expensive price, it is not worth to take into consideration.

<table>
<thead>
<tr>
<th>Result</th>
<th>Remarking</th>
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</thead>
<tbody>
<tr>
<td>Failed</td>
<td>No 3D function</td>
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</tbody>
</table>

4. Solidworks Standard 2013

SolidWorks is a 3D mechanical CAD program that is being developed by Dassault Systèmes SolidWorks Corp., which is currently used by over 2 million engineers and designers at more than 165,000 companies worldwide. As a CAD software designed for mechanical drawings, the usage of Solidworks is similar to Autodesk Inventor. It utilizes a parametric feature-based approach to create 3D models and assemblies. At the same time, it could be competent to finish most of the 2D drawings tasks.

The largest advantage of this kind of software design is intuitive and easy to learn and understand. The example below shows part of the procedure to draw the 3D model of a part.

Define base shape and parameter

Extrude the solid base

Draw the profile on the face
Cut the solid along the profile

Draw the profile of another feature

Extrude the feature and mirror the solid

**Figure I.6  Example to draw 3D modeling in Solidworks**

As a specific mechanical 3D drawing software, Solidworks provides plenty of functions of 3D features, and 2D sketches. The toolbars are shown in the figure I.7. In particular, the Smart Dimension function in 2D sketch is convenient to set and show the dimension of 2D profile.

**Figure I.7  3D features toolbar in Solidworks**

**Figure I.8  2D sketch toolbar in Solidworks**

The Solidworks meets the core requirement of the company, thus it is worth to have the trial.

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<thead>
<tr>
<th>Result</th>
<th>Remark</th>
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<tbody>
<tr>
<td>Approved</td>
<td>Extensive 3D modeling functions</td>
</tr>
</tbody>
</table>

5. **PTC Creo**

The former name of PTC Creo is PRO/Engineering, which is a famous 3D mechanical drawing software. Although it is a competitive potential choice, it had been faced the installation error for times. After the installation, the program could not be opened because of fatal error. The pop-up could be grasped in the figure I.9. The technical support could not be contacted because the Customer Service Access is the exclusive access for paying customers. The re-installation has been proceeded several times, but the problem could not be solved. The incident reflected the instability of the software to some extent, which led to the disqualification of PTC Creo to the software trial.

**Figure I.9  Install failure for Creo**
Economical software

CAD options in the lower end of the price range are particularly worth considering. Many, in fact, offer features and functionality that seem could rival with popular ones like Solidworks. The question is are they sophisticated enough to be easy to learn and use productively.

1. FreeCAD 0.13

FreeCAD is aimed directly at mechanical engineering and product design but also fits in a wider range of uses around engineering, such as architecture or other engineering specialties. FreeCAD is currently in a beta stage of development.

During the test, it is found that the software is really hard to use and the link of tutorial on the front interface is invalid. It is not a suitable choice to select it as the final decision.

<table>
<thead>
<tr>
<th>Result</th>
<th>Remarking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failed</td>
<td>Install failure</td>
</tr>
</tbody>
</table>

2. Sketchup 2013

SketchUp is one of the greatest free CAD packages ever put on the market. The free version has no limitations and it provides one of the simplest 3D design interfaces. Even if the people who have never done any CAD work or 3D modeling before, they can have some really nice models in minutes.\(^{[34]}\)

The software has simple toolbar, as the picture showed below.

![SketchUp toolbar](image)

Every time when clicking one of the functions, a guiding pop-up will appear to help the user.

However, if the user is looking to put out detailed designs, with accurate sizing and tolerances, he will need to spend some time learning the ins and outs of the program. Because the software provides the simplest functions in the front interface, it is easy to build a house or a table. And if the user need to create a detailed design, the skills on combination of functions are required. In the document format support aspect, SketchUp support import and output AutoCAD .dwg files.

The most serious barrier to add the SketchUp into short-list is the lack of mechanical drawing transfer, parts assembly and fix, and the interface of 2D drawing sheets. For this reason, SketchUp is out of consideration.

<table>
<thead>
<tr>
<th>Result</th>
<th>Remarking</th>
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<tbody>
<tr>
<td>Failed</td>
<td>Lack of mechanical drawing features</td>
</tr>
</tbody>
</table>
3. **ZW3D 2014**

ZW3D is integrated CAD/CAM software for concept design to final machining work includes 3D modeling, mold design and machining functions. It is based on technology acquired from VX Corporation.\(^{[35]}\) ZW software is a CAD software provider with headquarter in Guangzhou, China.

ZW3D is another feature-based modeling software like Solidworks or Inventor. Its drawing targets include part, assembly and drawing, and every aspect contains the similar functions as other feature-based modeling software. The motto of this product, “Design more, pay less”, shows its main attraction, the lower price. The standard version of ZW3D cost € 2500, which contains assembly function and 2D drawing function. It is an attractive software, and it has been listed into the trial software to see whether it is worth to purchase.

<table>
<thead>
<tr>
<th>Result</th>
<th>Remarking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approved</td>
<td>Enough(seem) functions and attractive price</td>
</tr>
</tbody>
</table>

4. **Rhinoceros 5**

Rhinoceros (Rhino) is a stand-alone, commercial NURBS-based 3-D modeling software, developed by Robert McNeel & Associates.\(^{[36]}\) It is recommended by a seller of software vendor. Non-uniform rational basis spline (NURBS) is a mathematical model commonly used in computer graphics for generating and representing curves and surfaces.\(^{[37]}\)

The usage of this software is similar to SketchUp, which means the model is easy to establish but is not parametric modeling. User can edit any surface by control point. It is very easy to create an organic shape modeling. But, user is quiet hard to re-modify when the model has been completed.\(^{[38]}\) Also, it lacks many important needed features like convenient dimension definition, parts assembly and fix.

The Rhinoceros is proved to contain the capability of making mechanical CAD drawing while it is not the strong point of this software. Its modeling method is hard to start for the learner. So the Rhinoceros will not be taken into consideration.

<table>
<thead>
<tr>
<th>Result</th>
<th>Remarking</th>
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<tbody>
<tr>
<td>Failed</td>
<td>Unsuitable modeling method, hard to re-modify the sketch</td>
</tr>
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</table>
5. BricsCAD

BricsCAD from Bricsys integrates 3D direct modeling with a nonribbon-based interface that is similar to recent AutoCAD. It is introduced in an article about low-cost CAD by Cadalyst which is a popular CAD magazine.\[^{39}\]

In 2011, Bricsys acquired the intellectual property rights from Ledas for constraints-based parametric design tools permitting the development of applications in the areas of direct modeling and assembly design.\[^{40}\]

Direct modeling is an opposite approach of 3D modeling compared with parametric modeling. It allows designers to interact directly with the geometry of the model. This means they can manipulate it by pushing, pulling, or twisting. It doesn’t need parent/child relationship. Meanwhile, BricsCAD retain the assembly function which is prior to build a large installation.

After the preliminary test, three dissatisfactory issues about 3D CAD were found, though in promotional website, all the features are competent.

1) The operation, including the model rotation, feature extruding and so on, is not as fluid as other similar software. The user could obviously feel the suspending. The hardware of test computer fits the requirement of the software and there is no similar problem happened in the test of other software.

2) Limited 3D modeling function

As an alternate of AutoCAD, BricsCAD has an outstanding performance in 2D mechanical drawing, while its 3D function design is not easy to use and the functions are limited. No guide to lead the designer use the functions. No introduction on all the buttons. No plane choice when starting a sketch. Swept, loft, thread functions and so on are missing.

3) Unfriendly toolbar

Meanwhile, the interface is similar to the recent version of AutoCAD, which is less friendly than the popular “ribbon” interface, because all the functions are crowded together.

![Figure I.12 Toolbar of BricsCAD](image)

The BricsCAD uses the special method to model the 3D drawing, which could have been the advantage of the software. However, the hard-to-use interface design and limited provided 3D functions make it become not suitable for the non-experienced staff in this case.

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<thead>
<tr>
<th>Result</th>
<th>Remark</th>
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<tbody>
<tr>
<td>Failed</td>
<td>hard-to-use interface design</td>
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</table>

6. HiCAD

It is said that HiCAD is a user friendly CAD software. The trial application was submitted for weeks and up to the finish date of draft report, there is no reply from the manufacturer. So the arranged review was cancelled.
Appendix II: ZW3D guide material

1) An example of the pop-up window for function explanation

![Pop-up window for hint in ZW3D](image)

**Figure II.1** Pop-up window for hint in ZW3D

2) Some of the official training manuals

![List of training manuals](image)

**Figure II.2** Overview of provided training manual
3) Some of the official tutorial videos in YouTube

Figure II.3  Playlists of ZW3D tutorial video in YouTube
Appendix III: Supported formats of Solidworks

<table>
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<th>Parts Export</th>
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Figure III.1 Detail supported formats of Solidworks
Appendix IV: progress to connect two sub-parts together in Inventor LT

In the example, a Tee pipe and a reducer were created and they are ready to be connected together.

1. Create the base component

![Figure IV.1 Example Tee connection in Inventor](image1)

2. Derive the Reducer component

![Figure IV.2 Derive order explanation](image2)
3. The reducer is imported and the import coordinate is zero.

![Image of reducer](image3.png)

**Figure IV.3** Import the reducer

4. Create the reference plane and measure the distance in x axes.

![Image of distance measurement](image4.png)

**Figure IV.4** Measure the distance between two planes.

5. Choose the Move Bodies function.

![Image of Move Bodies function](image5.png)

**Figure IV.5** Move Bodies function
6. Move the reducer -30mm in x axes.

![Figure IV.6 The Reducer moves to the correct position in x axes](image)

7. Create the reference axes and measure the distance in y axes.

![Figure IV.7 Measure the distance between two axes](image)
8. Move the reducer 30mm in y axes

Figure IV.8 the pop up window to set the offset

9. The Reducer moved to the correct position

Figure IV.9 Connected two sub-parts
Appendix V: Tricks and tips of operation of ZW3D

1) Central button of mouse

If the central button of mouse is pressed, it means the user request for the last order. For example, if the fillet function is proceeded, the user could order it again by pressing the central button of mouse.

Another function of this button is configuration. If the parameters of one function are filled in, the user can directly press central button of mouse instead of clicking the tick to send the order. For example, when proceeding the fillet function, the edges have been selected and the radius has been input. At that time, users can just press central button of mouse. It reduce the movement of mouse and fasten the operation speed.

2) Axes selection

The x,y,z axes can be chosen directly in any related functions, like mirror, pattern, to be used as reference lines. Users could save the time of building reference lines.

3) Unlink reference line

The reference line function is frequently used. When creating new sketches, the existed geometry may be needed. In ZW3D, users can use the reference line as the sketch line after the import by unlink reference line function. As shown in the figure, a geometry will be extracted as a sketch step by step.

| In sketch mode, the existed geometry cannot be selected directly | Order to create the reference line. The reference line cannot make effect when creating new feature. | Right click the reference line (red line of dashed), and choose unlink reference. | The reference line become active line which can be used as the sketch. |
4) Multiple select

Designers usually have the need to select several lines. ZW3D provides a function to select the closed curve at one time. Hold the Shift key on the keyboard, and select one of the segment, the software will select other ones. An example is shown below.

| The reference lines are created at first. | Moving the mouse to one of the lines and it becomes yellow. | Holding the shift key and selecting that line. All the lines belong to that closed curve are selected. |
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