Performance Evaluation of 3D-Model CAAD Implementation in Dutch Architecture Firms

Mandau Apri Kristianto
Email: makristian@student.han.nl
Master Dissertation for MSc. in Architectural Management
South Bank University, London – the United Kingdom
In cooperation with
Hogeschool van Arnhem en Nijmegen – the Netherlands

Supervised by:
Dr. Shamil Naoum (SBU), Email: Naoums@sbu.ac.uk
Alfred Meijers (HAN), Email: meijers.architect@planet.nl

SUMMARY: *The principal theme of this research is to provide information regarding the implementation of 3D Model CAAD, CAAD system which uses 3D Drawing Production Method (DPM) instead of 2D DPM. This research is focused on its implementation in architecture firms and on justifies its performance and investment value. Principally there are two evaluations conducted in this research. First evaluation aimed to justify 3D-Model CAAD influence on design process and the second is investment evaluation which aimed to provide information for current and prospective user regarding their current and future investment on 3D-Model CAAD.*

The results of the evaluations are: 3D Model CAAD has improved performance through efficiency on time and cost of design process also improvement on design quality. However correlation between the use of 3D-Model CAAD and better performance, while tested using Chi-Square Test, is not significantly. This fact indicates that there are some other strong factors to influence design performance. Second, 3D-Model CAAD, according the Importance-Performance Map is positioned at top right quadrant which categorised as 'keep the good work' which means it has good investment value.

KEYWORDS: *Evaluation, Performance, 3D-Modeling CAAD, Investment, Drawing Production Method*

1. INTRODUCTION

The evaluation of Information Technology (IT) is defined as "a process that places at different points in time or continuously, for searching for and making explicit, quantitatively or qualitatively, all the impacts of an IT project" (Peter E.D. Love & Zahir Irani., 2001). The evaluation of IT investment, as well as the function, has received widespread attention in the IT and business literature, often because there are significant amount of monies involved in developing an IT infrastructure. Yet, it remains relatively unexplored in construction, albeit to a few studies (Peter E.D. Love & Zahir Irani., 2001). Albeit there were only few studies, the evaluations of IT implementation have successfully revealed important findings namely: it's found that organisations in the construction industry do not use any form of cost-benefit analysis to evaluate their IT investments (Peter E.D. Love et. Al., 2000) and construction organisation regarded the use of evaluation technique as a "ritual of legitimacy", which were costly to implement and therefore, did not generate value to decision-making process (Andersen J., 1999 as cited in Peter E.D. Love et. al., 2000). These facts show that most IT applications so far are bought into the industry without planning and evaluation. The result has been that the full potential of IT to improve organisations' efficiency, effectiveness and flexibility has seldom been reached. (Love, P.E.D. et. Al., 2000).

In Architecture, the most important area of IT in architectural design is the use of computer-aided architectural design (CAAD). This tool has brought benefit through shortened time required to provide architectural drawings and documentation. The early CAAD concept was introduced by Ivan Sutherland in his thesis at the Massachusetts Institute of Technology (MIT) in 1963. However the commercial breakthrough of CAAD was happened in 1980s with the advent of the personal computer. This resulted in CAAD popularity to automate drafting process and have been proved bring significant improvement in design process (Mays, Vermon. 1997). Later on, CAAD evolve to become more sophisticated tools with new technology which instead of draw a line between two numerically defined points, creates building model based on 3D Object.

2. DEFINITION OF 3D-MODEL CAAD

Definition of 3D-Model CAAD in this research referred to definition on 'Modern CAD system' by John Mitchell and Roger Miller which has characteristics such as: based on 'different concepts' and has vastly improved capabilities compared with earlier systems. Firstly, they store and manipulate objects in a true three-dimensional geometric environment. Secondly, CAD systems can now store other information about these objects in addition to size, shape and position. These properties are called up, stored and manipulated by designers and builders. They may be introduced, expanded or enhanced at different phases of the project, by the appropriate participant. Thirdly, CAD systems can 'understand' the relationships that an object may have to other objects. These relationships may be direct and explicit: for example, windows and doors 'know' that they belong to particular walls. (Cited from Rick Best & Gerard De Valance, 1999).

Different concept stated by John Mitchell and Roger Miller, referred to Naai-Jung Shih (1996) classifications on drawings productions methods. According to him, 3D-Model CAAD was classified in 'Building model and applying references files' drawing production methods. This drawing production methods use three-dimensional models with complete building information to generate drawings. In other words, this method constructs a building model during the design process then if drawing is requested, drawings are projected or cut from this building model. This methods is different to 2D CAAD or 'Segregating drawing files' because it generate drawings from model as single source instead of creating drafting separated files from single lines which is common in 2D CAAD. Interface used in 3D CAAD is categorised as "input≠output" (input not equal to output), whereas interface used in 2D CAAD is "input=output" (input equal to output).This method is proposed to benefit in improving coordination of drawings, speedier communication of design alternatives and reduced field work. In addition, employing model-based design produces richer, more highly structured data that is useful beyond the design phase. (CADServer, 2002)

3. STATEMENT OF PROBLEM

3D-Model CAAD has been well established in academic circle for a quarter century but it was only in the last few years that practicing architects have begun to pay serious attention due to some shortage felt by current 2D CAAD user (Randall S. Newton., 2001) also due to aggressive marketing by CAAD vendors to expand their market (Jerry Laiserin., 2001). The application of 3D-Model CAAD in architecture firms is an interesting object to be evaluated because of a tendency that it's taken up slowly by the users and doesn't give benefits as expected albeit it offers many advantages (Rivard, H, 2000; Arif, A.H. Karam, 2001; Business Advantage, 2001; O. Samuelson, 2002).

The principal theme of this research is to provide information about the implementation of 3D-Model CAAD in architecture firms which will focus on evaluating its performance as well as its investment value. As the architecture industry is becoming more technology driven, investments in IT are likely to increase in the future therefore its evaluation is critically important. In addition, this research is also important because this topic is still unexplored area in construction industry and it was found that implementation and use of CAAD is mainly (information) technology driven in which the decisions concerning the use were rarely based on anything other than the desire to gain experience with this rather new technology (Chandansingh, Reynold., 1995). Furthermore the purpose of this dissertation is to justify an existing system and to enable learning experience for improving subsequent system development practice.

4. RESEARCH AIM, OBJECTIVES & HYPOTHESIZES

The research aim is "**to analyse the current implementations of 3D-Model CAAD in architecture firm and to determine the economical impact of the implementation 3D-Model CAAD in design process."**

In order to achieve the aim, this writer broke down the aim into four objectives, namely:

1. To find out the implementation of 3D-Model CAAD in Architecture Firm.
2. To appraise the benefits, limitation and other barriers for application of 3D-Model CAAD.
3. To justify performance improvement brought by 3D-Model CAAD.
4. To justify the investment made on the implementation of 3D-Model CAAD.

As for hypothesizes of this research are:

1. 3D-Model CAAD has improved performance through efficiency on time and cost of design process also improvement on design quality.
2. Investment in 3D-Model CAAD has been profitable, not solely because time and cost efficiency but also from the emerging of new functions.

5. THE SURVEY

Survey was conducted by sending approximately 500 survey invitations to architecture firms which are listed at Bond van Nederlandse Architecten web site (www.bna.nl). Large number of respondent was targeted for this survey in order to make this study can be regarded as a representation of the whole industry.

As for the mean of data collection, web form published at **http://www26.brinkster.com/caadsurvey** is used. A strong argument for the use of electronic survey methods is the lower relative cost of e-mail surveys when compared with traditional mail surveys. (Kenneth K., et al 2002). However there are also some potential limitations of web survey such as coverage error, systematic bias and low response rate. In this survey, these limitations hopefully can be minimized because of some conditions, namely:

- According to CBS (2002) 82% companies in the Netherlands have access to internet connection which indicates that coverage errors will less likely to happen in this research because of high level of internet use in the Netherlands.
- Systematic bias will also less likely to happen in this survey because drawing from the technology acceptance model by Davis et al., (1989) and Agarwal & Prasad (1999) that an individual's prior experience with using computing technology in one area is positively related to that individual's beliefs about ease of usage for another computing technology. Thus, a Web-based survey to assess the implementation of CAAD, might find a higher level of adoption of that technology, relative to an identical mail-based survey. (Cited from R.D. Klassen, J. Jacobs., 2001).

Furthermore to anticipate low response rate, email reminder was sent and incentive such as access to summary of findings was offered. However after one month survey (January – February 2003) and two reminder letters sent, there are only 33 respondent participated. This is show a response rate of 6.45% (See Table 1). Nevertheless low response rate, this survey doesn't loss its credibility because majority of respondents (63%) are in top/middle management level who knows exactly matter of the survey.

Table 1 Research Sample: Number and rate of response by category

Email Sent	No Respond	Email Error	Refused	Total Respond		Response Rate
				Complete Survey	Incomplete Survey	
511	427	40	11	30	3	**6.45%**

6. RESPONDENT PROFILE

6.1 Size of Firms

Reviewing the data collected about the size of firms, there is a wide range that extends from a one-person-office to an office of more than 50 staff-members (only involved in design-process). There are a high percentage of small-sized offices in the area, about 53.57 %, where the number of employees does not exceed five people. It illustrates the nature of the architectural services and indicates the viability of running small offices where they could be easily sustained by a few members of staff.

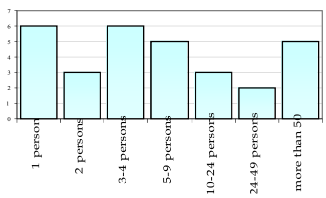

Figure 1 Size of Firms

6.2 Age of Firms

Architectural firms participate in this survey, for the most part; have been in operation for a lengthy period of time. The oldest responding firm that is still in operation was established in 1959, and in contrast, the youngest operating one was established in 2002. Fig 2 shows the highest percentage of firms (32 percent) occurring at the 5-15 years category.

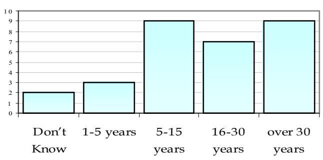

Figure 2 Age of Operating Firms

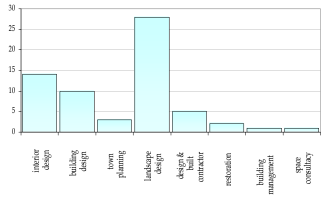

Figure 3 Area of Specialty

6.3 Area of Specialty

The work of these offices varies considerably by type. However, there are some areas of concentration. Although some offices rank more than one area as being there area of specialty, they show that the landscape design ranks the highest source of work at. Interior Design ranked second and building design is ranked at number three.

6.4 Out Sourcing

Majority (55.33%) of Architecture firms in this survey don't out-source part of their design work to other firm. And some of them (21%) do involving other firm. The remaining (26.67%) didn't have any knowledge on this matter. From open ended question which accompany this question, it's known that part of design works which mostly out-sourced are: engineering (technical) specification, building cost calculation and presentation.

7. GENERAL FINDINGS

7.1 Period of Using CAAD

All respondents have ample experience with CAD because most of them have more than 5 years experience.

There are 2 firms which have a relatively new experience with CAAD (1-3 years) but it happens due to relatively news firms.

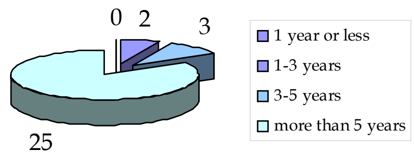

Figure 4 Period of Using CAAD

7.2 CAAD Software Used

Most popular CAAD Software is AutoCAD followed with VectorWorks, ArchiCAD and Autodesk Architectural Desktop. AutoCAD as the popular software is similar to those of Canada, Nordic Countries and South Africa (Rivard 2000; Samuelson 2002; Arif A & H. KAram 2001). In those countries AutoCAD dominate the software market. Indeed in Nordic countries it is used by more than 50%. According to the result also can be determined that the most popular 3D-Model CAAD Software is ArchiCAD from Graphisoft (6 users) and followed by Autodesk Architectural Desktop (5 users).

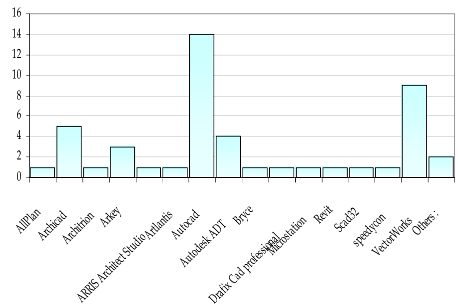

Figure 5 CAAD Software used (unprompted)

7.3 Number CAAD Used Vs Number of Staff

There are 23 firms (76.67%) of firms providing CAAD system to all of their staff which left 7 firms (23.33%) of them aren't providing CAAD system to all of their staff. High percentage of firms providing CAAD system is an indication how important CAAD system for aiding design process. It also shows how dependent design process is to CAAD system. Firms which don't provide CAAD to its entire staff don't mean that they less dependent to CAAD system, but it may happen because of complex organization structure which involves supervisors or managers who, presumably, do more managerial and less drawing/design work. Indeed this assumption is supported by the fact that this condition only happen in middle to big size firms (more than 5 design staff) which usually have more complex organisation structure.

Table 2 Number CAAD Vs Number of Staff

Number of Staff (persons)	Staff Using CAAD (persons)						
	1	**2**	**3-4**	**5-9**	**10-24**	**25-49**	**>50**
1	**6**	-	-	-	-	-	-
2	-	**3**	-	-	-	-	-
3-4	-	-	**6**	-	-	-	-
5-9	-	-	1	**4**	-	-	-
10-24	-	-	-	1	**2**	-	-
25-49	-	-	-	-	2	-	-
>50	-	-	-	-	-	3	**2**

8. 3D-MODEL CAAD IMPLEMENTATION

8.1 Drawing Production Method Used

Table show that there are more firms (60%) which applied 3D-Drawing Production Method (3D-Model CAAD user) compared to firms which applied 2D CAAD (40%).

From firms who applied 3D-Model CAAD can be divided into firms who fully applied 3D-Model CAAD and who applied it in combination with 2D CAAD, namely: 46.67% applied full 3D Model CAAD and 13.33% in combination with 3D CAAD.

Table 3 Drawing Production Method Used

2D-CAD	3D Model CAD in combination with 2D CAD	3D Model CAD
40.00%	13.33%	46.67%

This condition is a contrast compared to conditions in other countries such as Canada, Nordic and UK (Rivard, 2000; Samuelson, 2002; Business Advantage, 2002), where the use of 3D-Model CAAD is rarely used. However this figure can't be regarded as indication of 3D-CAAD popularity in the Netherlands because it seems to be possible that firms with other drawing production method (2D CAAD and Manual) hesitate to participate in this survey. This is indicated by several refusal letters which say that they aren't participating in this survey because aren't using 3D-Model CAAD software.

8.2 Period of Using 3D-Model CAAD

The table shows that almost half (44.44%) of respondent has implement 3D-Model CAAD for more than 5 years. This result followed with 27.78% of them who implement 3D-Model CAAD for 3-5 years. High percentage of firm who implement 3D-Model CAAD for more than 5 years may indicate that for some firms drawing production method based on a model has become their method of work for sometime which proved to be effective.

Table 4 Period of Using 3D-Model CAAD

1 year or less	1-3 years	3-5 years	more than 5 years
11.11%	16.67%	27.78%	44.44%

8.3 Frequency the use 3D-Model CAAD during Design Tasks

3D-Model CAAD has been highly implemented in design tasks such as: Modelling, Rendering & Animation; Conceptual Sketching; Design Development and Space Planning with average rate of 3.67, 3.61, 3.28 and 3.11 respectively. In addition, 3D-Model CAAD also has moderate level implementation in Space Programming with average rate of 2.83. Nevertheless 3D-Model CAAD is low implemented in Analysis & Evaluation and Construction Document & Specifications with average rate of 1.94 and 2.17.

Table 5 Frequency the use of 3D-Model CAAD

Design Task	Average Rate
Space Programming	2.83
Conceptual Sketching	3.61
Space Planning	3.11
Design Development	3.28
Analysis & Evaluation	1.94
Modeling, Rendering & Animation	3.67
Construction Documents & Specifications	2.17

These results indicate that 3D-Model CAAD have been implemented widely in early design process but it have been negligently applied in late design process, in exception for Modelling, Rendering & Animation. However the low level use of 3D-Model CAD in those design tasks may be in relation with the fact that architecture firms out-source some of the design task (see profile 4.4) especially for technical works which mostly happen in the late design process.

Compared to the earlier system, 2D CAAD, 3D-Model CAAD used more frequently in 'Conceptual Sketching' and 'Modelling, Rendering & Animation'. However in any other design tasks, 3D-Model CAAD falls behind its predecessor, especially in 'Construction Documents & Specifications'. Based on this finding, the writer concludes that user still unable to exploit the full benefits of 3D-Model CAAD. 3D-Model CAAD' visualization ability is the only one benefits which is better exploited by user.

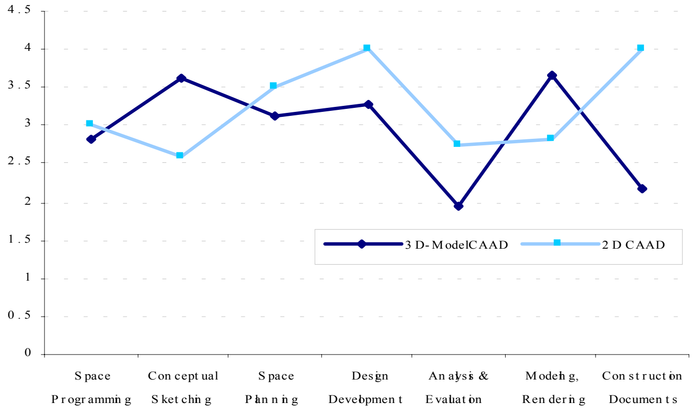

Figure 6 Frequency the use of 3D-Model CAAD compared to 2D

8.4 Factors Influencing Decision to Use 3D-Model CAAD

In similar fashion with categorizing IT/IS cost, writer argues that IT/IS benefit can be categorized into two categories namely 'IT/IS tangible benefit' and 'IT/IS in-tangible benefit'. The tangible benefits are the change in cost and revenue; in addition the in-tangible benefits are improvement in design management efficiency and some strategic advantages.

Table 6 Factor Influencing Decisions

	Average Rate
It will deliver some strategic advantages	3.39
I will improve design management efficiency	3.22
t will bring about some increase in revenue	3.00
It will change the firm's cost for the better	2.89

Table 6 shows that most respondents tend to think that the intangible factors are more influential factors than the tangible ones. High average rate of respondents who agree that 3D-Model CAAD will improve design management efficiency (3.39) and deliver strategic advantages (3.22) prove that statement.
However, this statement doesn't automatically mean that the tangible factors aren't influential to the decision because the figures on revenue and cost factors show a balance. The average rate show 3.00 and 2.89 which is indicate or closely indicate 'neither/nor' response to this question.

8.5 Limiting Factors to adopt 3D-Model CAAD

According to Non-3D Model CAAD (2D CAAD) user, 'Learning time or learning difficulty' is most limiting factor to adopt 3D-Model CAAD with average rate 3.92. Opinion of '2D CAAD is still adequate' is in the second with average rate 3.67 while Cost is positioned at third with average rate of 3.25.

Table 7Limiting Factors

	Average Rate
Learning Time/Difficulty	3.92
2D drafting or drawing is adequate	3.67
Cost	3.25
Partner/ Customer Attitudes	2.58
Irrelevant to Us	2.17

Other: the time is not right to invest in IT.

Findings on 'Learning Time/ Difficulty' as the most limiting factor support the finding in problems which mostly occur during the implementation 3D-Model CAAD (see findings 5.10) which positioned 'Lack of Skill and Lack of Training' as the most frequent problems (the average rate 3.61 and 3.50). This finding confirms the result of survey conducted by Lychgate Projects in 1999 (CICA, 2001) that found 'Lack of training' has been a major concern in 'IT usage in the construction team'.

8.6 Benefits of 3D-model CAAD Implementation

Table 8 shows that most of respondents agree that 3D-Model CAAD improves all conditions mentioned in the survey. This conclusion based on the fact that all rates are above neutral level.
3D-Model CAAD perceived the highest score on this ability to improve 'Correct Drawings' and 'Better Presentation to Client' (4.67), followed with 'Better to communicate idea among designer' (4.22) and 'Consistency among plans, elevations & sections' (4.11). These findings confirm theory by Naai-Jung Shih (1996) and come to a conclusion that 3D-Model CAAD benefits as stated by Naai-Jung Shih are substantially true.

Table 8 Benefits of 3D-Model CAAD

	Average Rate
Correct Drawings	4.67
Better presentation to client	4.67
Better to communicate idea among designer	4.22
Consistency among plans, elevation & sections	4.11
Better collaboration work between project participant	3.94
Preparation before drawing production	3.89
Potential for further data analysis	3.72
Reduce effort	3.44
Reduce involved persons	3.22
Reduce Time	3.11

8.7 Problems occur during 3D-Model CAAD Implementation

Table 9 shows that respondents rank 'Lack of Skill' as the most common problem occurred during 3D-Model CAAD implementation, with average rate 3.61. It's followed with 'Lack of Training' and 'Need to change existing design methods', with average rate 3.50.
Based on the result can be concluded that 'IT/IS indirect costs' are more dominant than 'IT/IS direct cost'. This conclusion supported with the fact that top three problems occur when implement 3D-Model CAAD are problems related to 'IT/IS indirect' cost. This condition supports the theory by Love and Irani (2001) which

Table 9 Problems occur during 3D-Model CAAD Implementation

	Average Rate
Lack of skill	3.61
Lack of training	3.50
Need to change existing design methods	3.50
Software is to complex	3.44
Bigger file size	3.39
High software cost	3.22
Difficulty to transfer existing data	3.06
High operation cost	2.94
Productivity loss	2.89
Difficulty to upgrade the system	2.83
High hardware cost	2.72

state that it's increasingly recognized that the 'indirect' cost associated with the adoption of IT are more significant than the 'direct' cost identified.
IT/IS Direct Cost which represented by 'Software Cost' only rank at 6. In addition, other direct cost such as 'Operation Cost' and 'Hardware Cost' ranked at 8 and 11. The fact that 'Hardware & Software Cost' is the less important factors supported statement by Rob Howard (1998) which stated that cost of hardware will decreased therefore number of user will increased.

8.8 CAAD System Vs Size of Firm

There are more small firms which implement 3D-Model CAAD Compare than big firms which implement 3D-Model CAAD. In contrast, there are less small firms which implement 2D CAAD compared with big firms which use 2D CAAD.
This result can be used to assume that it's easier for small firms to adopt new technology compared to the bigger ones. This due to fact that it's easy for small company to change the way they work compared to the bigger firms which usually have more complex organization structure.
Further it can be concluded that high capitals, which presumably belong to big firms, don't have correlation with high ability to adopt new technology. Indeed, this emphasis the fact that the cost of investment in IT/IS isn't limited to direct initial cost but also include indirect organizational/individual cost which, in many case, bigger than the initial direct cost.

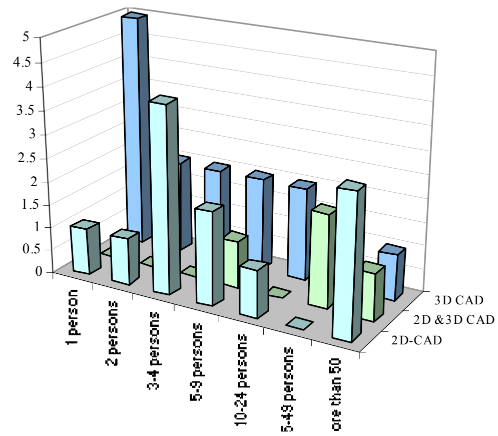

Figure 7 CAAD System Vs Size of Firm

9. THE EVALUATIONS

9.1 Design Performance Evaluation

Performance of design process is determined by three factors namely time, cost and quality. For this study, these three factors are quantified by using average rate of response on particular variables listed in the questionnaire. Here, the respondents were asked to mark each variable with rating scale '1' to '5'. Scale '1' means very bad and scale '5' means very good. Based in this responds then the mean value was calculated furthermore firms categorized according their performance value. Ones with average rate above the mean value categorized as 'High Performance' and ones with average rate below the mean categorized as 'Low Performance'. Variables used to measure design performance are listed as followed:

Table 10 Variable Used to Measure Design Performance

Factors	***Variables Used***		
Time efficiency	Its ability to shorten time needed for design process	Its ability to allow faster design process	
Cost efficiency	Its ability to make design process more economical	Its ability to improve staff productivity	
Quality	Its ability to produce quality drawings	Its ability to reduce the number of design errors	Its ability to improve overall design quality

However, performance improvement of can't be evaluated unless it's being compared. Therefore in this study, average rate of 3D-Model CAAD performance was being compared with one of 2D CAAD. By comparing both data, performance improvement, if it's occur, will be obvious with result of firms with 3D-Model CAAD will have higher performance as result of improved design performance.

Comments:
Table 11 show that there are more firms which used 3D-Model CAAD with 'High Performance' (34.48%) compared to ones with 'Low Performance' (27.59%). In contrast, for firms with 2D CAAD there are more firms with 'Low Performance' (24.14%) compared to ones with

Table 11 Performance of CAAD System

	High Performance		**Low Performance**		**Total**	
2D CAAD	5	17.24%	6	20.69%	11	37.93%
3D CAAD	10	34.48%	8	27.59%	18	62.07%

Notes: High Performance are Mean Value=4.02 & Median

'High Performance' (13.79%). These indicate that the first hypothesis, 3D-Model CAAD has improved design performance may be acceptable.

Statistical Calculation on Performance Evaluation
However to test the relationship between the use of 3D-Model CAAD with performance improvement in design process, it is proposed to conduct a statistical calculation on this issue. A statistical test which will be used to test the correlation is Chi-Square (X^2) test.

Hypothesis:
"3D-model CAAD has improved performance through efficiency on time and cost of design process also improvement on design quality".

Null hypothesis:
"3D-Model CAAD hasn't improved performance of design process".

Results:
The table 12 shows summary on the result of the calculation.

Statement of hypothesis testing
Calculated value of X2 is 0.28, therefore it's lower than the critical value of 0.455 for P<0.5 therefore the results of this research is not significant.

Table 12 Contingency table between CAAD System and design performance

	High Design Performance		Low Design Performance		Total
Firms with 2D-CAAD	1: 5	E= 5.69	2: 6	E= 5.31	11
Firms with 3D-Model CAAD	3: 10	E= 9.31	4: 8	E= 8.69	18
Total	15		14		29
X^2 =	0.28		df =	1	

Table 13 Distribution of X2

DF	Probability					
	0.5	0.1	0.05	0.02	0.01	0.001
1	0.455	2.706	3.841	5.412	6.635	10.827

Comment:
Based on the above findings, the following interpretations are made: Calculated value of X^2 larger than critical value was not happen, therefore first hypothesis: **"3D-Model CAAD has improved performance through efficiency on time and cost of design process also improvement on design quality" should be rejected and the null hypothesis should be accepted**. This conclusion to be accepted for this research due to fact that respondent perceived that type of CAAD system only one factor which influences performance of design process and there are some other factors which give influence to design process performance such as 'organization structure' and 'computer system'. Respondent's comments regarding these additional factors are: 'I think it's important to realise that the way CAD-systems are used in organisations depends not only on the system itself, but most of all in the way the organisation works' and 'I my opinion no improvement in CAAD without steady (computer) machine'.

9.2 Investment Evaluation
Majority of architecture firms participated in this survey (76.67% and 83.33%) doesn't evaluate their investment before or after the implementation of CAAD system. This finding confirms theory by Peter E.D. Love & Zahir Irani (2001) that most IT applications so far are bought into the (construction) industry without planning. However, regarding the importance of the evaluation which is asked as open-ended question, most of respondent agree that evaluation will improve their performance. Comments which represent this though such as: 'Of course, like all production factors, the CAAD system needs regular evaluation to keep it up to recent developments in CAAD and design practice'. This fact has lead to indication that there are factors which hindering architecture firms to conduct IT/IS evaluation.

As for method used to evaluate the investment, Importance-Performance (I-P) Maps is used. This method is originated in marketing and was developed by Martilla J.A and James J.C, (1977) to facilitate easy management diagnosis of new product success. This method rather measured 'soft measurement' than 'hard measurement' which used respondent perception of IT/IS investment success. Lack of financial information and time constraint were behind the decision to use 'soft measurement' instead of 'hard measurement'.

Briefly, I–P maps are a matrix-based technique that seeks to present customer perceptions of importance and performance in an easy to interpret format. Producing I–P maps begins with the generation of an agreed list of elements on which evaluation is conducted. From this, survey instruments are developed, often using ‘Likert’ or ‘Numerical’ scales, and these questionnaires are then administered to respondents. Finally, the importance and performance of the identified elements are plotted against each other.

Interpreting I–P maps is relatively straightforward, involving the mapping of elements to one of four types. *‘Concentrate here’* refers to elements that are perceived as important but where performance is lacking. *‘Keep up the good work’* are those elements that are both important and are being delivered to a high level. *‘Low priority’* elements are those that are recognized as both being of low importance and only small performance, making improvement unnecessary. Finally, *‘possible overkill’* refers to elements that are being over delivered, having high performance and low importance.

Table 14 Category means for 3D-Model CAAD

	3D-CAAD	
	I	P
System Quality	4.37	4.02
Information Quality	4.37	4.08
Use	4.24	4.12
User Satisfaction	4.09	3.94
Individual Impact	3.73	3.96
Organizational Impact	3.81	4.05

Statistical Calculation on Investment Evaluation

For this research guidance model of Information System (IS) Success Framework by De Lone & Mc Lean (1992) is used. This model used six elements to determine the success of IS project, namely: System Quality, Information Quality, Use, User Satisfaction, Individual Impact and Organizational Impact. In addition, five point numerical scales were developed for both importance and performance of the elements. These were anchored by ‘very important’ and ‘little important’ for the former and ‘very good’ to ‘very bad’ for latter. Result regarding the importance and performance value of 3D-Model CAAD is presented in table 14 by means of its means value. Furthermore, these values are plotted to a matrix as showed at figure 8.

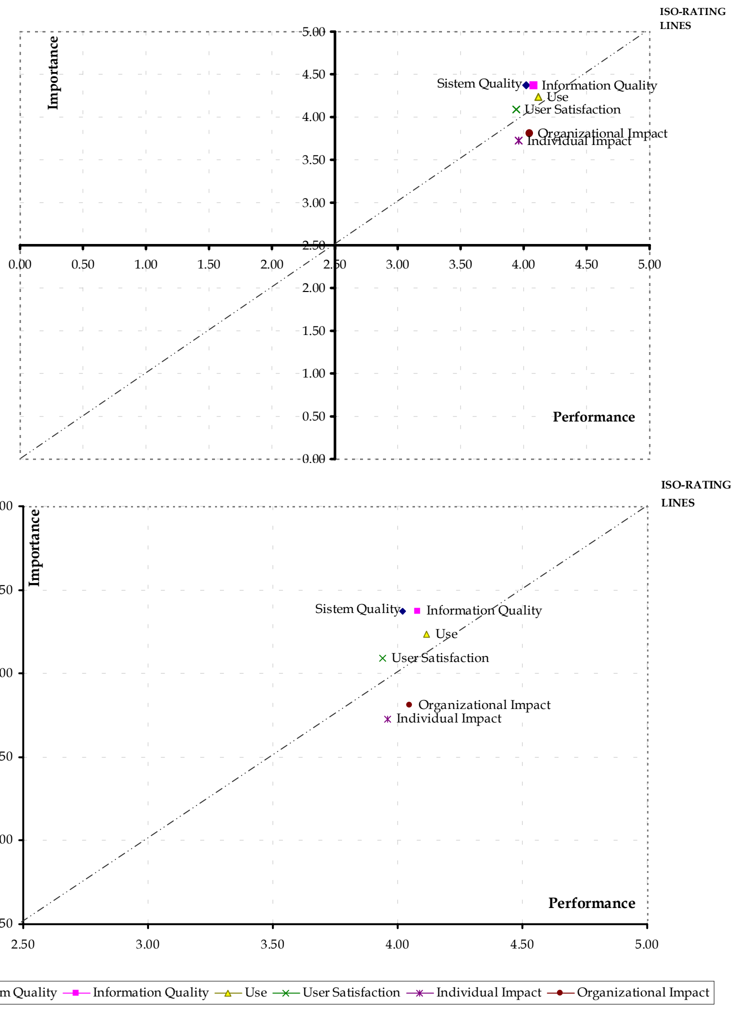

Figure 8 I-P Map in categories for 3D-Model CAAD

Hypothesis:
"Investment in 3D Model CAAD has been profitable, not solely because time and cost efficiency but also from the emerging of new functions".

Statement of hypothesis testing:
The I-P maps show that all variable placed at the top-right quadrant which represent elements of high performance/high importance, the prescription being '*to keep the good work'*. According to this position therefore it's clear that 3D-Model CAAD perceived as successfully matching needs and performance in all of its aspects. This condition suggests that the **investment made on 3D-Model CAAD is worthwhile therefore the hypothesis for this study can be accepted.**

Comments:
Concentrating on the diagonal 'iso-rating line', it is immediately apparent that there are four of six elements of 3D-Model CAAD which positioned above the line which fall into *opportunities*. This means that these four elements achieve less performance than ought to be (the importance). These four elements are: System Quality, Information Quality, Use and User Satisfaction. By knowing elements categorised as *opportunities*, it opens possibility for improvement. Priorities of improvement can begin from one with greater importance namely: First are 'System Quality' & 'Information Quality'; second is 'Use' and third is 'User Satisfaction'.

10. CONCLUSION
Regarding achievement on first objective **'to find out the implementation of 3D-Model CAAD'**, the writer finds that it was successfully achieved by random survey conducted toward BNA (Bond van Nederlandse Architecten) members. Some important findings regarding these objectives are:

1. There is more architecture firms in the Netherlands which implement 3D-Model CAAD compared to ones with traditional CAAD (2D CAAD). However this finding only can be regarded as early indication due to small sample of survey.
2. Most of 3D-Model CAAD users are already used it for long period, more than 5 years.
3. 3D-Model CAAD has been implemented mostly in early design process. Compared to the earlier system, 2D-CAAD, 3D-Model CAAD less frequently used in almost every design tasks, except 'Conceptual Sketching' and 'Modelling, Rendering & Animation'.
4. 3D-Model CAAD use mostly by small architecture firms.

Conclusion regarding this objective is: The author finds that 3D-Model CAAD has been extensively implemented in the Netherlands but potential benefit failed to be exploited. This opinion is based on the fact that it's widely use and it has been used for relatively long time but it doesn't intensively used because only 3D-Model CAAD' visualization ability is optimally used.

Regarding achievement of second objectives which is **'to appraise the benefits, limitation and other barriers for application of 3D-Model CAAD'**, the author finds that information needed was gathered successfully through the survey. Based on this information, there are several findings which need to be underlined concerning perceived benefit, limitation and barrier, which are:

1. Current 3D-Model CAAD user states that their decision to deliver strategic advantages and improve design management system is the most influential factors to adopt 3D-Model CAAD.
2. Current 3D-Model CAAD users agree that 3D-Model CAAD has improved design process conditions. Three conditions which perceived to be most affected are: 'Correct Drawings', 'Better presentation' and 'Better idea communication'.
3. 3D-Model CAAD users mostly agree on seven factors which they found as problems during 3D-Model CAAD Implementation. 'Lack of Skill' perceived as the most limiting factor followed with 'Lack of Training' and 'The Need to Change Existing Design Methods'.
4. According to non 3D-Model CAAD (2D CAAD) users, there are three factors which limiting them to adopt 3D-Model CAAD, which are: 'Learning Time/Difficulty' and '2D is still adequate' and 'Cost'.

Conclusion regarding result on second objectives is: Attempt to evaluate 3D-Model CAAD need to be focused more on intangible benefits and indirect costs because these are major concern on 3D-Model CAAD Implementation. This conclusion based on the fact that decision to gain intangible benefits is dominant for investment decision also this benefits is dominant to be perceived by 3D-Model CAAD user.

In similar vein, indirect factors are the most common problems occur during 3D-Model CAAD implementation which inhibit CAAD user to adopt 3D-Model technology.

Regarding achievement of third objectives which is **'to justify performance improvement brought by 3D-Model CAAD'** was achieved by collecting information from respondents concerning performance of 3D-Model CAAD. In this study, performance of design process was determined by quantify response on variables which can be categorized as time, cost and quality. These factors were measured using 5 scale linker scales. Then by using its mean value, firms were categorized based on their score on these three factors into two categories namely high and low performance. The result show that there are more firms with high performance compared then the ones with low performance, with composition of 56% (10 firms) with high performance and 44% (8 firms) with low performance. This show better result compared to 2D CAAD since there are more firms with low performance (55%) then one with high performance (45%).

After a statistical test (non-parametric statistical test: chi-square) is conducted to measure 3D-Model CAAD significance to design performance it's found a calculated value of X2 = 0.28 that is lower than the critical value of 0.455 for $P<0.5$. Based on this results therefore can be concluded that the **first hypothesis '3D-Model CAAD has improved performance through efficiency on time and cost of design process also improvement on design quality' is not proved** because it's true that architecture firms which implement 3D-Model CAAD have improved performance (high performance) but the relationship isn't significant. This may indicate some others factors which also determine design performance.

Finally, regarding the last objective of this dissertation which is **'to justify the investment made on the implementation of 3D-Model CAAD'** was achieved by collecting information from respondent concerning level importance and performance of 3D-Model CAAD Implementation. There are 18 questions asked to measured the importance and performance of 3D-Model Implementation and it's cover not only 3D-Model CAAD performance but also some other aspect of its implementation such as user satisfaction, individual and organizational impact. This decision was aimed to prove research hypothesis **'Investment in 3D-Model CAAD has been profitable, not solely because time and cost efficiency but also from the emerging of new functions'.**

According to I-P Maps, it showed that all variables of 3D-Model CAAD positioned at 'keep good work area' which mean that 3D-Model CAAD proved to bring performance better than it ought to be. In investment, it means that investment on 3D-Model CAAD is worthwhile for the firms. In organization level it could be mean cost reduction and potential increase of revenue. **Therefore conclusion regarding this objective is 3D-Model CAAD has brought positive economical impact (profitable) on design process which proved the second hypothesis of this research.**

9. RECOMMENDATION

Research on area of design process is a really interesting area of study because it observes design process through a completely different view, in case of this study is management 'know how'. This sort of research revealed findings which usually claimed to be part of architects' intuition. This research has discovered the importance of CAAD system to aid the process and the fact that, for current design process is almost un-separate with the use of CAAD. However this research found that CAAD System is not sole factor which influence the process, because there are other factors such as computer system and how the process is organized which also can be regarded as influential factors. This fact has inspired idea for future research which is a research to identify factors which influencing performance of design process. Result of this proposed research will be a model which describe each factors and explain how these factors affect the process. This proposed model hopefully can become guidance for architecture firms to make a strategy for achieve the optimal performance. Some factors which can be tentatively categorized into these influential factors namely: 'software used', 'computer system used' and 'organization structure'.

As for the implementation of research findings, the author recommends that investment evaluation conducted in this research is only an indicative study which need to be coupled by 'hard measurement' for further study. This recommendation is based on theory by W. Skok et al. (2001) and Charles R. Duke and Andrew S. Mount (1996) who point out several weaknesses of Importance–Performance (I-P) Maps.

According to W. Skok et al. (2001) there are two weaknesses of I-P maps. Firstly, I–P maps clearly sacrifice depth for breadth and convenience; they are unlikely to provide the detailed insights found from, say, in-depth interviews. Yet, management may be prepared to make this sacrifice depending on their priorities. Indeed, I–P maps could be used as a preliminary device to allow areas requiring more detailed analysis to be identified. Second, I–P maps are attitudinal in nature, relying on people's perceptions of IS success and not, for example, 'harder' measures such as financial returns or 'actual use' statistics. The inability to account for such metrics should be a recognized weakness of the I–P approach. In addition, according to Charles R. Duke and Andrew S. Mount (1996) limitations of performance-importance charts include a lack of statistical significance testing ability and sensitivity to the section of scale used in the visual presentation. Performance-importance charts are meant to augment, not replace, statistical comparisons of critical issues. The charts may help to indicate or to highlight issues not previously considered, but conventional statistical tests must be used to determine significance.

10. REFERENCES

- Arif, A. H. Karam (2001). **'Architectural Practices and Their Use of IT in The Western Cape Province, South Africa'** IT for Construction Vol. 6 (2001), p. 17. [Online] Available at http://www.itcon.org/2001/ (accessed 10 October 2002)
- Best, Rick; De Valence, Gerard (1999) **'Building In Value Pre design issues**' London: Arnold.
- Business Advantage (2002) **'3D AEC Intelligence Quest'**. CAD Spaghetti January 2002. [Online] Available at http://www.business-advantage.co.uk/spaghetti/3d.htm (accessed 10 October 2002)
- Chandansingh, Reynold A (1995) **'The economic value of CAD Systems in Structural Design and Construction'** Delft: Delft University Press.
- CBS (2002). **'De Digitale Economie 2002'** Centraal Bureau voor de Statistiek.
- CICA (2001). **'Making IT Work for Your Business: Architectural IT Usage and Training Requirements.'** CICA Report 2001. [Online] Available athttp://www.cica.org.uk/arch_IT_usage-training_briefing.pdf (accessed 10 October 2002)
- De Lone W.H & Mc. Lean E.R (1992) **'Information Systems Success: The quest for dependent variable'** Information System Research March (1992) 60-98.
- Duke C.R and Mount A. S (1996). **'Rediscovering performance importance analysis of products'** Journal of Product & Brand Management, Vol. 5 No. 2 1996 pp. 43-54 © MCB University Press, 1061-0421.
- Howard, Rob (1998). **'Computing in Construction Pioneers and the Future'** Guildford: Butterworth Heinemann 1998.
- Joan A. Ballantine and Stephanie Stray (1999) **'Information Systems and Other Capital Investment'** Logistics Information Management 12 Number 1 / 2 – 1999 p. 78-93.
- Klassen R.D. & Jacobs J (2001) **'Experimental comparison of Web, electronic and mail survey technologies in operations management'** Journal of Operations Management 19 (2001) 713–728.
- Mays, Vermon (1997) **'Does CAD boost productivity?**' Architecture (IAI) Magazine June 1997.
- Naai-Jung Shih (1996). **'A Study of 2D- and 3D-oriented architectural drawing production methods'**. Automation in Construction 5 (1996).
- O. Samuelson (2002). **'IT-BAROMETER 2000 the Use of IT in the Nordic Construction Industry'** IT for Construction Vol. 7 (2002), p. 1. [Online] Available at http://www.itcon.org/2000/ (accessed 10 October 2002)
- Peter E.D. Love, Zahir Irani (2001), **'Review Evaluation of IT costs in construction'**, Automation in Construction 10 (2001) 649-658.
- P.E.D. Love, Z. Irani, H.Li, R.Y.C. Tse, E.W.L. Cheng, '**An empirical analysis of IT/IS evaluation in construction**'. International Journal of Construction Information Technology 8 (2) (2000).
- **'2D to 3D challenge – Autodesk on Architectural Desktop'**, CAD Server [Online] Available at http://www.cadserver.co.uk/common/viewer/archive/2002/Jan/16/feature5.phtm (accessed 10 October 2002)
- Rivard, Hugues (2000). **'A Survey on The Impact of Information Technology on The Canadian Architecture,Engineering and Construction Industry'** IT for Construction Vol 5 (2000). Pg. 37 [Online] Available at http://www.itcon.org/2000/ (accessed 10 October 2002)
- Schmitt, Gerhard (1999). **'Information Architecture-Basis & Future of CAAD'**. Basel: Birkhäuser.
- W. Skok, A. Kophamel, I. Richardson (2001) '**Diagnosing information systems success: importance–performance maps in the health club industry'** Information & Management 38 (2001) 409–419.