A Web Based Case-Based Reasoning System for HVAC Sales Support

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Abstract: This paper describes the implementation of a CBR system to support HVAC sales staff operating in remote locations. The system operates on the world wide web and uses the new standard of XML as a communications protocol between client and server side Java applets. The paper describes the motivation for the system, its implementation, trial and roll-out detailing the benefits it has provided to the company.

1. Introduction

Western Air is a distributor of HVAC (heating ventilation and air conditioning systems in Australia with a turnover in 1997 of $40 million (Australian dollars AUD). Based in Fremantle the company operates mainly in Western Australia, including isolated communities in the Great Sandy, Great Victoria, and Gibson deserts; a geographic area of nearly two million square miles. The systems supported range from simple residential HVAC systems to complex installations in new build and existing factories and office buildings.

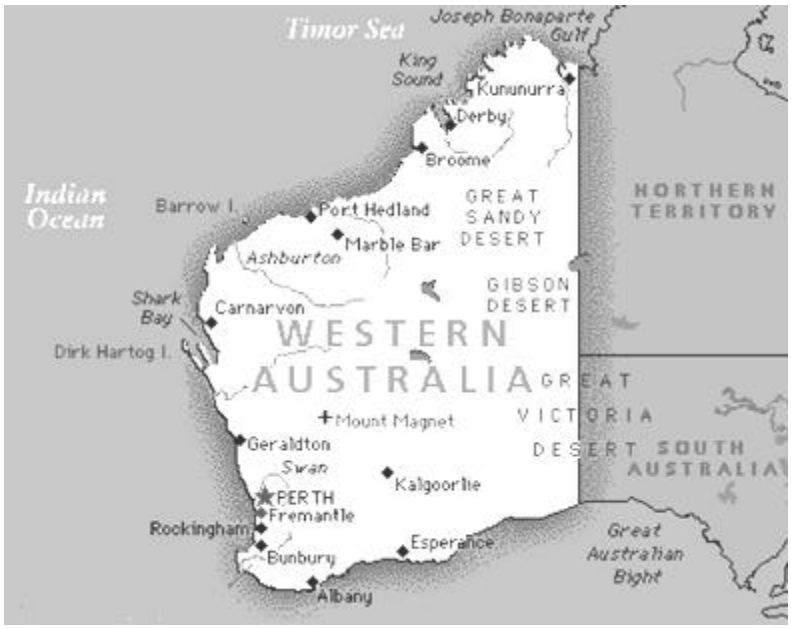

Figure 1. Map of Western Australia

2. The Problem

Western Air has a distributed sales force numbering about 100. The majority of staff do not operate from head office but are independent, working from home or a mobile base (typically their car). In fact many sales staff seldom visit Fremantle. The sales staff are technically trained being required to take a four week training course covering most aspects of the systems they supply. They do not install systems, this work is done by specialist sub-contractors.

Simple installations, such as a set of window or exterior wall mounted AC box units can be easily specified, and priced by even the most novice sales staff. However, the specification and cost estimation of more complex systems involving roof mounted AC units, ducting, fans and sensors requires the expertise of a fully qualified HVAC engineer. Western Air employs about five fully qualified engineers (two of whom are the firms owners). Until recently, sales staff in the field would gather the prospective customer's requirements using standard form and proprietary software, take measurements of the property and fax the information to Western Air in Fremantle. A qualified engineer would then specify the HVAC system. Typically the engineer would have to phone the sales staff and ask for additional information. Usually the sales staff would have to make several visits to the customer's building and pass additional information back to the engineer.

The engineer would then specify and cost the installation and a quote would be prepared and faxed to the sales staff. The sales staff would forward the quote to the customer and is empowered to negotiate on price within set margins. However, if the customer then decided that perhaps they needed fewer sensors or now only wanted certain zones in the building cooled the sales staff would have to contact the engineer and the cycle would repeat.

This process could take several weeks if the engineers were busy with other work and during this process the sales staff may be detained "*beyond the Black Stump"* (Australian slang for *"a remote place"* such as Kununurra in the far north) or loose the sale to a competitor.

Engineers when preparing specifications and quotes use a variety of specialised software to calculate HVAC loadings and made extensive use of previous installations. In particular Western Air felt that basing a quote on the price of a previous similar installation gave a more accurate estimation than using prices based on proprietary software, catalogue equipment prices and standard labour rates. However, they were aware that they were not making use of all their past work. They had nearly ten thousand system installation files but most engineers only made use of their *favourite* few dozen. To try to help engineers make use of all the past installations a database was created to let engineers search for past installations. The database records contained about 30 to 60 fields describing the key features of each installation and then a list of file names for the full specification. These might be MS Word documents, Excel files or AutoCAD files.

Initially the engineers liked the database and it increased the number of past installations they used as references. However, after the honeymoon ended, they started to complain that it was too hard to query across more than two or three fields at once. And that querying across ten or more fields was virtually impossible. In fact most of them admitted to using the database to laboriously

browse through past installations until they found one that looked similar to their requirements.

3. The Solution

Western Air realised they wanted a system that could find similar installations without making the query too complex for the engineers. By chance they employed a new engineer who had done a computing Masters degree in the UK that had introduced CBR to him. Web based CBR applications have been demonstrated for a few years now such as the FAQFinder and FindME systems [1] and those at Broderbund and Lucas Arts [2]. Dan therefore felt that CBR on the web was suited for this project and contacted AI-CBR[1] for advice.

Western Air decided that merely improving the efficiency of the engineers in Fremantle would not solve the whole problem. Ideally they would like the sales staff to be able to give fast accurate estimates to prospective customers on the spot. However, they were aware that there was a danger that the less knowledgeable sales staff might give technically incorrect quotes.

The solution they envisaged was to set up a web site that sales staff could access from anywhere in the country. Through a forms interface the prospect's requirements could be input and would be passed to a CBR system that would search the library of past installations and retrieve similar installations. Details of the similar installations along with the ftp addresses of associated files would then be available to the sales staff by ftp. The sales staff could then download the files and use these to prepare an initial quote. All this information would then be automatically passed back to an engineer to authorise or change if necessary. Once an installation was completed its details would be added to the library and its associated files placed on the ftp server.

3.1 Expected Benefits

Western Air expected the following benefits:

- A reduction in the time taken to turn around sales quotes from an average of five days to two days. It was estimated this might save approximately $250,000 a year.
- An increase in the accuracy of their estimates allowing them to judge their margins better and be more competitive. If they were able to reliably increase their margins (whilst keeping their quotes competitive) by 1% it would increase Western Air's profits by $500,000 a year.

3.2 The Team

The development team comprised:

- a senior engineer from Western Air (one of the firms owners) as project champion,
- an engineer from Western Air to act as project manager and domain expert,
- a consultant Java/HTML programmer,
- a consultant from AI-CBR to advise on CBR issues (resident in the UK), and
- a part-time data entry clerk.

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[1] http://www.ai-cbr.org

3.3 Implementation Plan

The project had the direct involvement of one of the firms owners so management commitment was not a problem. It was also decided that creating a partially functional prototype was not sensible since the system would either work or not. However. a carefully controlled and monitored trial was considered essential for two reasons:

1. It was still not certain that sales staff could create technically sound first estimates and therefore a small carefully monitored trial was essential to avoid losing the firm money.
2. There were resource implications since although all sales staff had portable PCs, some were old 486 Windows 3.1 machines and few had modems or Internet accounts.

A fixed (non-negotiable) budget was given to the project of $50,000 and it was decided that six months would be given for development and trial of the system. The project started in October of 1997 and the trial was planned for March of 1998.

It was decided initially to deal with moderately complex residential HVAC systems because it was felt that this would provide a reasonable test of the system without undue risk. Western Air felt that it was commercially unwise to risk experimentation on high value commercial contracts.

3.4 Hardware & Software

A Windows NT server was purchased to act as both web and ftp server. It was decided to keep the HVAC information in the original database (MS Access) since this would remove the need to create a new case-library. An evaluation of commercially available CBR tools with web facilities was undertaken including Inference's CasePoint WebServer, ServiceSoft's WebAdvisor, and Brightware's Art*Enterprise [2]. Inference and ServiceSoft's products were eliminated because they are designed for diagnostic customer support and predominately handle textual case data. Brightware's product although technically suitable was rejected on cost grounds.

Since a simple nearest neighbour retrieval algorithm would almost certainly suffice implementing our own system was a viable option. Java (Visual Café) was chosen as the implementation language for both the client and server side elements of the CBR system. The new standard XML (eXtensible Markup Language) [3] was used as the communication language between client and server-side applets. The World-Wide Web Consortium (W3C) finalised XML 1.0 in December 1997 as a potential successor to HTML [4]. HTML provides a fixed and limited tag set, whereas XML authors can define an unlimited number of tags. XML therefore can incorporate commands that can be interpreted by applications and user-defined attribute:value pairs. Thus, XML is a natural communications standard for distributed intelligent systems operating on the web. There is presently (June 1998) no commercially available web browser that supports XML 1.0 but it is possible to develop Java applets that can interpret XML and display the results in the browser window.

3.5 System Architecture

On the sales staff (client) side a Java applet is used to gather the customer's requirements and send them as XML to the server. On the server side another Java applet (a *servlet*) uses this information to query the Access database to retrieve a set of relevant records. The Java servlet then converts these into XML and sends them to the client side applet that uses a nearest neighbour algorithm to rank the set of cases.

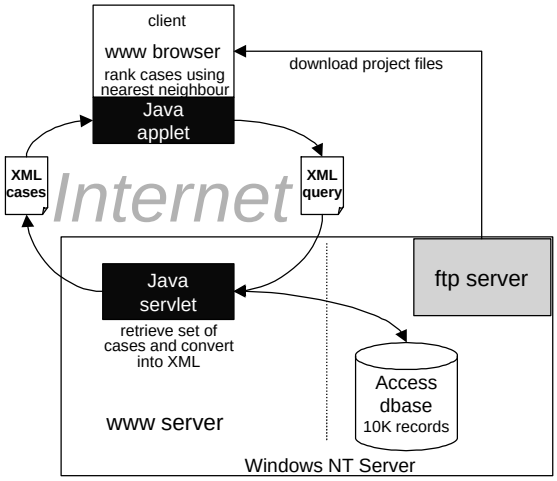

Figure 2. System Architecture

3.6 Case Representation

Cases are stored permanently within the Access database as conventional database records. Each record (case) comprises between 30 to 60 fields used for retrieval and many more used to describe the HVAC installations. In addition, links to other files on the ftp server are included to provide more detailed descriptions.

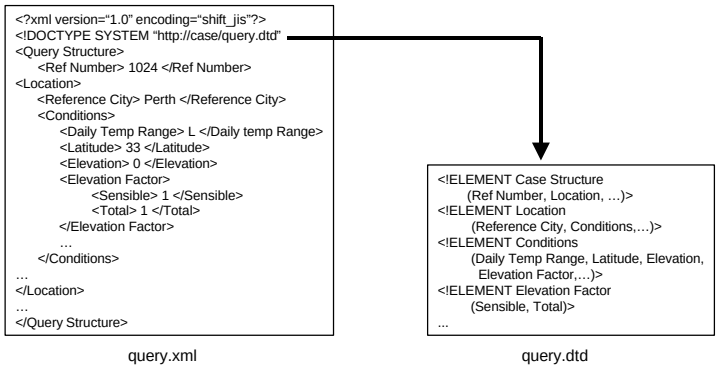

Figure 3. A sample of the XML case description

Once retrieved from the database the records are ranked by a nearest neighbour algorithm and dynamically converted into XML for presentation to the client browser. A similar XML case representation to that used by Shimazu [5] is used by our system. XML pages can contain any number of user defined tags defined in a document type definition (DTD) file. Tags are nested hierarchically from a

single root tag that can contain any number of child tags. Any child tag in turn can contain any number of child tags. Each tag contains a begin statement (e.g. <Case>) and an end statement (e.g. </Case>). This is illustrated in Figure 3.

3.7 Case Acquisition

Western Air had already put a considerable amount of effort into developing their HVAC installation database, which was used as the case library for our system. Consequently the project was fortunate in not having to acquire cases or pre-process them. However, knowledge engineering was required to create similarity metrics and obtain default weightings for the retrieval algorithm. This was not surprising as the similarity measure is one of the most important *knowledge containers* of any CBR system [6].

3.8 Case Retrieval

Case retrieval is a two stage process. In stage one the customer's requirements are relaxed through a process of *query relaxation*. What this process does is to take the original query and relax certain terms in it to ensure that a useful number of records are retrieved from the database. This is similar to the technique used by Kitano & Shimazu [7] in the SQUAD system at NEC. For example, let us assume that we are trying to retrieve details of properties in or near Perth in the South West of the state. An SQL query that just used "Perth" as a search term might be too restrictive. Using a symbol hierarchy our system knows that Perth is in the South West of the state so the query is relaxed to "Where (((Location,ReferenceRegion) = "SW")..)). This query will include installations from Perth, Fremantle, Rockingham and surroundings. Similarly specific elevations or temperatures can be relaxed to ranges (e.g. "Between 60 And 70").

```
SELECT Location.ReferenceRegion, Location.DailyTempRange,
Location.Lattitude, Location.Elevation, Location.ElevationFactorS,
Location.ElevationFactorT, Location.DryBulbTempWin,
Location.DryBulbTempSum, Location.WetBulbTemp,
…
FROM Location
WHERE (((Location.ReferenceRegion)="SW") AND ((Location.Elevation)
Between 0 And 100) AND ((Location.DryBulbTempWin) Between 50 And
60) AND ((Location.DryBulbTempSum) Between 60 And 70))
…
```

Figure 4. Example of an SQL query that has been relaxed

Determining exactly how the query could be relaxed involved knowledge engineering and for example involved creating symbol hierarchies for location, building types and usage. The Java servlet queries the database to retrieve a set of broadly similar records. If enough records are not retrieved (five is considered to be enough) the query is relaxed further. If too many records are retrieved (too many is more than 20) then the query is made firmer to reduce the number. Once a sufficient set of records has been retrieved they are converted into XML and sent to the client-side applet.

In the second stage the small set of retrieved records are compared by the client-side applet with the original query and similarity is calculated using this simple nearest neighbour algorithm:

$$Similarity(T,S) = \sum_{i=1}^{n} f(T_i, S_i) \times w_i$$

where:
T is the target case
S is the source case
n is the number of features in each case
i is an individual feature from 1 to *n*
f is a similarity function for feature *i* in cases *T* and *S* and
w is the importance weighting of feature *i*

Western Air expressed some surprise at the necessity for this second step and did not see the need for calculating a similarity score. Initially they felt that it would be sufficient to just show the small set of retrieved records. However, during the trials the sales staff found that the similarity score was useful. Moreover, once they understood the principle they could override the default feature weightings if they wished which they also found useful. Changing the weightings let them reflect either the customer's preferences or their own experience.

3.9 Case Retention

Once an HVAC installation is completed its details are added to the Access database and its associated files placed on the ftp server. Having a database management system for the case repository has proved very helpful since it makes it easier to generate management reports and ensure data integrity. It would be almost impossible to maintain a collection of 10,000 cases without a DBMS.

3.10 Interface Design

The interface to the system is a standard Java enabled web browser (Netscape or Internet Explorer). The forms within the Java applet were designed to look as similar to the original forms, HVAC specification tools and reports that the sales staff were already familiar with. Microsoft FrontPage 98 was the primary tool used to create the web site.

3.11 Testing

Two weeks before trial five test scenarios were created by the project's champion. These were representative of the range of more complex residential installations the system would be expected to handle in use. The project's champion an experienced HVAC engineer knew what the *correct* answers should be. These were given to the five sales staff who would initially use the system and they were asked to test the system. Out of the 25 tests (5x5) 22 were correct. Although the remaining three were not specified as expected they were felt to be technically acceptable solutions.

3.12 Roll-Out

The system was rolled out for trial to the five sales staff in March of 1998. At first the project's champion monitored all the projects that were being processed by the system. As his confidence grew in the system this was reduced to a weekly review.

Acceptance of the system from the five sales staff was very good once they understood what it was doing. At first they expected it to be calculating HVAC loads as the software they had previously used had done. Once they understood that it was interrogating Western Air's database of HVAC installations they understood how it could be used to provide them with much more than just HVAC loads. During the month's trial the system dealt with 63 installations all of which were felt to be technically sound. The sales staff had not had to use the expertise of the HVAC engineers at all for this work although the engineers checked the final specifications.

4. System Demonstration

The following screen captures provide a feel for how the system looks and feels. The first screen shows part of the capture of the customer's requirements.

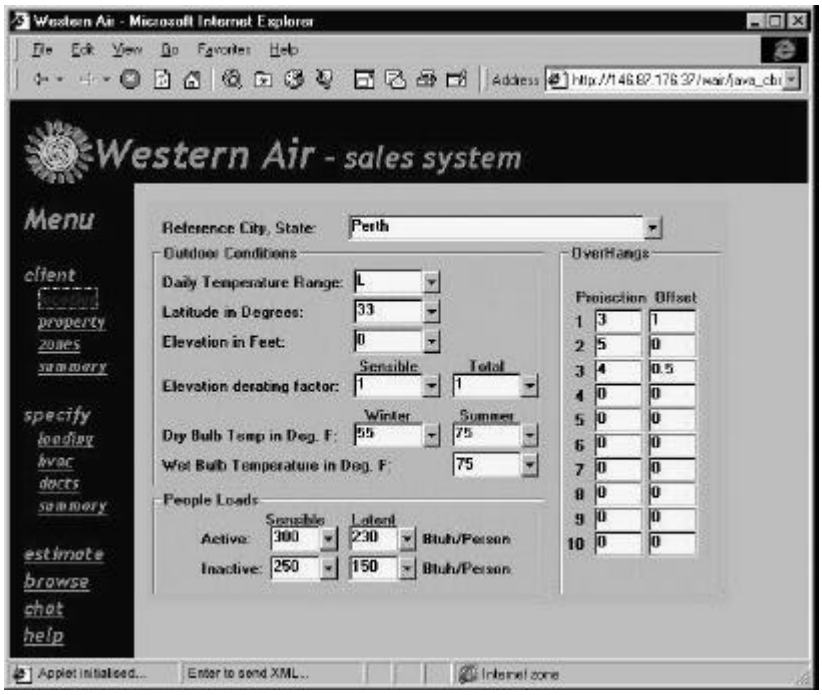

Figure 5. The Java applet showing property location

The next screen shows a retrieved case (judged 95% similar) detailing the specification and performance of the HVAC equipment. The subsequent screen shows specification for ducting and finally the last screen shows a summary screen detailing HVAC loads in the customer's living room.

Figure 6. Java applet showing retrieved case HVAC details

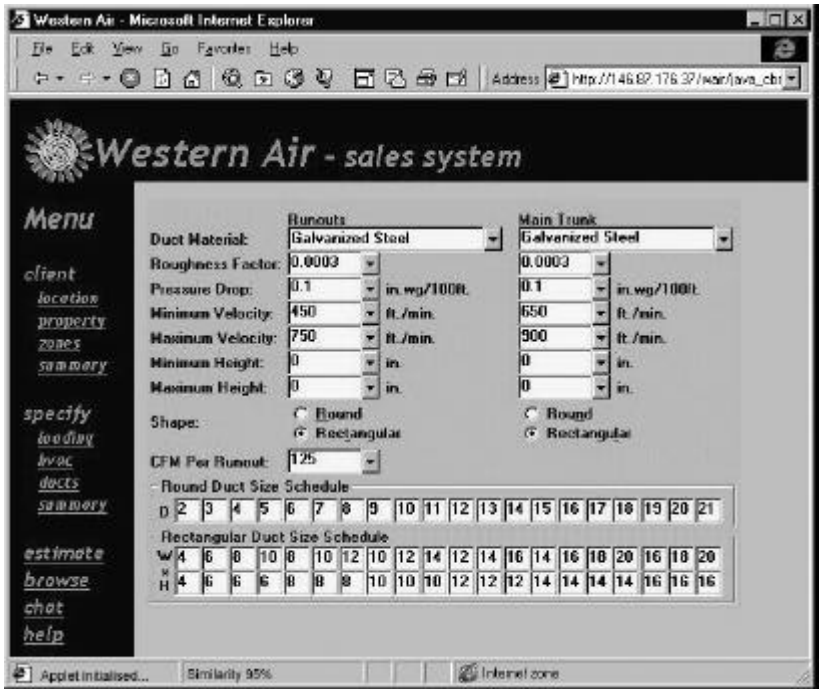

Figure 7. Java applet showing specification of AC ducting

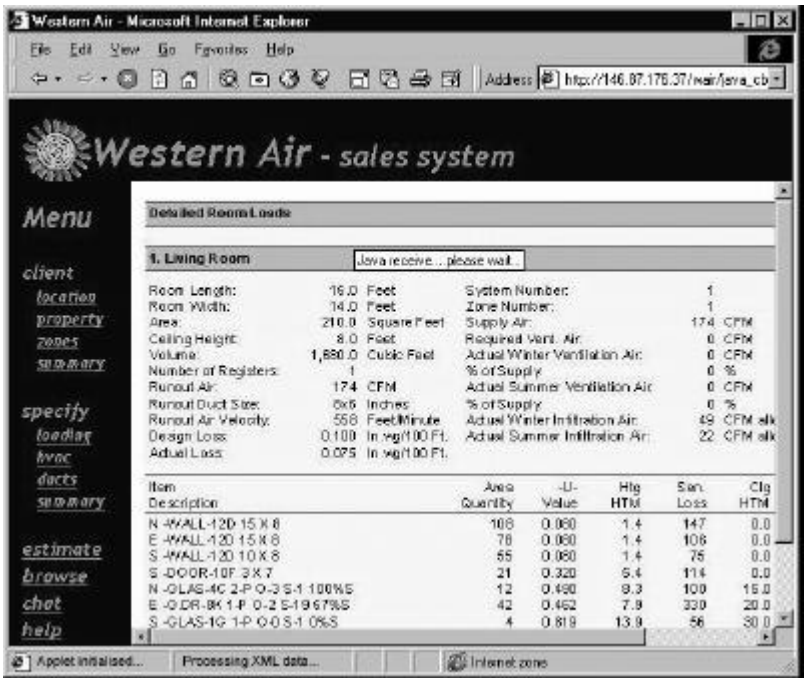

Figure 8. Java Applet showing summary of room HVAC loading

5. Benefits

During the trial month the five sales staff were able to handle 63 installation projects without having an HVAC engineer create the specification. This resulted in a considerable saving in engineers time allowing them more time to deal with complex high value commercial HVAC contracts. It was estimated that margins had been increased by nearly 2% while still remaining competitive. Based on this Western Air has invested $200,000 in purchasing Pentium notebook PCs for its sales staff. The system was rolled out to the entire sales staff in May of 1998. Western Air are expecting profits to increase by $1 million in the first year directly attributable to this system – a more than reasonable return on the investment of $300,000.

One of the firm's senior engineers commented that: "*Since this system went live I've had much more time to spend on my own contracts. I used to hate going into the office because I always had a string of problems to handle from the mob out in the field. Now I feel I have the time to really help when I do get a problem to deal with.*"

A member of the sales staff said that: "*This is just great. It used to be really frustrating waiting for them back in Fremantle to deal with our problems. I always had to give 'em aggro and when we did finally get an answer the bloody customer changed his mind. Then they whinge because we can't give them an answer on the spot. Now I can even use their phone and get good answers real quick. It really impresses them!*"

6. Conclusions

This implementation has shown how a distributed CBR system can be created on the web in a relatively short space of time. Implementing the system for web delivery made the system much more viable. Just a few years ago we would have had to install the entire system (including the database of 10,000 records) on each of the sales staffs PCs. We would then have had to regularly send them updates to the database. This would have significantly increased the operational costs of the system. Thus the web is an ideal medium for delivering intelligent support of all types.

The project was most certainly helped by having a ready made case library. Although some knowledge engineering work was still required in determining valid ways of relaxing the SQL queries and creating similarity metrics. At first we thought we'd just link to the Access database and do all the work in Access using macros. But the Java applets were probably easier to create and XML is a useful communications protocol enabling large packets of formatted information to be exchanged thereby reducing network traffic. As a possible replacement to HTML it should help the web support intelligent applications [8, 9]. With hindsight we should have evaluated the CBR-Works product by the German company tecInno (www.tecinno.de) since it has much of the functionality we required and they have had some notable successes with web based CBR systems for technical sales support [10].

However, Western Air are very impressed with the system and after the successful trial felt that they had a strong business case to obtain the necessary investment to upgrade all the sales staff computers. Feedback on the first months use is positive and they are now thinking how they can use the web to support other activities.

6.1 Update

Some three to four month has passed since this paper was submitted to the ES98 conference. In that time the system described here has left the protective care of those closely involved in its development and testing. It has been rolled out to the entire sales staff and there have been some problems. Mostly these were due to poor information and training of the staff who were initially unsure of how they were expected to use the system and what their new role and responsibilities were. As a result most of the sales staff were called in for a two day training session that involved familiarising themselves with the system and with the concepts that underlie it. Role playing was used to show how the system can be used to "clinch" a deal and the staffs' ownership of the system was emphasised.

In the first three months since the system has been fully operational sales compared with the same period last year are up almost 10% and margins have increased by 1.75%. Western Air may not make the estimated one million dollars profit in the first year, but they will not be far off!

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