

Report on the Interactive Voice Response System

1. Background information

1.1 The 2004 Legislative Council (“LegCo”) Election was held on the 12th September 2004. The Registration and Electoral Office (“REO”) was to report the cumulative hourly voter turnout figure from all 501 polling stations. An Interactive Voice Response System (“IVRS”) was deployed to serve this purpose.

1.2 However, there was a significant failure to the reporting process via this IVRS. This had led to the incomplete reporting of voter turnout figures from some polling stations that in turn delayed the announcement of the final turnout figure after the close of poll.

1.3 An investigation about the incident was conducted by staff of the Operations Division of the REO with IT expertise. Detailed information was supplied by the IVRS vendor, Continuous Technologies International Limited (“CTIL”), and the Technical Services Team of the Election Division of the REO in charge of the project. Raw data including event logs of the servers handling the incoming calls and the contents of the database on polling day were examined.

2. Functions of the IVRS

2.1 The REO, based on experience from 2003 District Council Election, decided to use the IVRS to automatically collect electoral statistical figures through telephone calls from all 501 polling and counting stations. The major advantage of using the IVRS is to seamlessly collect the required information from the 501 polling stations in a timely manner. These

electoral statistical information include:

- a. Opening time of all 501 polling stations.
- b. Voter turnout figures of all 501 polling stations for Geographical Constituencies (GCs) and Functional Constituencies (FCs) on an hourly basis.
- c. Complaint statistics of all 501 polling stations, 18 District Offices and the Committee & Research Division of the REO at three-hour intervals.
- d. Counting results from 485 counting stations.

3. Sequence of events on polling day

3.1 The following paragraphs describe in detail the sequence of events that took place on polling day:

Before 08:00 am	All 501 polling stations reported the opening status via the IVRS with no hiccups.
08:30 am	During the first period for reporting voter turnout figure, 34 polling stations failed to report any voter turnout figure and another 34 polling stations reported only partial voter turnout information (GC's turnout figure was reported but some of the FC's turnout figures were missing).
09:30 am	For the second period for reporting voter turnout figure, 37 polling stations failed to report any voter turnout figure and another 26 polling stations reported only partial voter turnout information.
10:30 am	For the third period for reporting voter turnout figures, REO's IVRS hotline received calls from polling staff reporting that the telephone calls to IVRS were occasionally cut off during

the reporting process. This situation was immediately referred to CTIL for follow up.

On examining the actual contents of the database, it was noted a total of 41 polling stations failed to report any voter turnout figure for the third period and an astonishing 224 polling stations provided only partial voter turnout information. (Due to the call flow, the GC's turnout figure was reported first, followed by FC's turnout figures. Partial information means GC's turnout figure and turnout figures for some FCs. The missing information was all FC related turnout figures.)

CTIL noticed the situation and initiated their troubleshooting immediately. They found out that the primary database server was running constantly at 100% CPU loading. This was abnormal and CTIL suspected there might be a hardware problem.

CTIL triggered the pre-defined contingency to switch the operation of primary database server to the secondary database server hoping to resolve the problem. After the secondary database server had taken up the workload successfully, the same 100% CPU situation re-appeared. This led CTIL to conclude that the problem was not hardware related and should be related to the software system that was developed for this event.

11:30 am

The situation deteriorated and the number of polling stations that could report complete voter turnout figure dropped to only 116, while 332 reported partial information and 53 failed to report any voter turnout information.

CTIL worked through the event logs of the servers that were answering telephone calls and checked the database and discovered that a particular procedure¹ that was executed might have caused the problem. This particular procedure

¹ More details will be discussed in the section "Findings of the investigation".

was executed every time an incoming call was received. Its main function was to calculate and return the accumulated voter turnout figures of all related constituencies (GC + FC) of the calling polling station. The way this procedure was being designed was to calculate from scratch, starting from the first period to the current period, every time these figures were required. As the number of reporting periods increased, the volume of data increased and the time required for the calculation also increased.

11:30 am
to 4:30 pm

This period of five hours was the time reported by CTIL being used in modifying and testing the system to arrive at the patch that they believed could resolve the problem.

2:50 pm
to 4:10 pm

REO's IVRS Team discovered that the interface file used by IVRS to transfer data to the Information Services Department for public release was damaged and contained erroneous data. CTIL was immediately notified and they triggered the pre-defined contingency plan to replace the interface file template with the backup copy. A five-minute delay as compared with the original schedule was noted and operation was back to normal at 4:10 pm. No further problem was reported for the data transfer for the rest of the polling day.

5:00 pm
to 5:30 pm

The patch for the "problematic" procedure was applied to the production system. At 5:30 pm, the reporting period immediately following the patch, the reporting process was back to normal with only 27 polling stations failing to report any voter turnout figures and 24 polling stations reporting partial information. It was not sure whether this partial information was caused by the insufficiency of the patch, or otherwise.

The patch applied was to skip both the calculation of the accumulative voter turnout figures and its verification by the IVRS with the polling station staff. These were confirmed and reflected in the log sheets of significant events, P(8) form,

from many PROs. Instead of storing these accumulative voter turnout figures in the database, they were computed by the system as and when required.

5:30 pm to
7:00pm

As there were still polling stations which could not report their voter turnout figures after the patch was applied, Technical Services Team raised their concerns on the integrity of the voter turnout figures. After some discussions, both parties agreed on an “Emergency Plan” which should be executed at close of poll after the final reporting period.

The “Emergency Plan” was to manually collect the final total voter turnout figures of both GC and FC from all 501 polling stations. The collected data would then be verified against those figures in the database before final release.

6:30 pm to
8:00 pm

The performance of the voter turnout reporting dropped again at periods ending 6:30 pm and 7:30 pm with 208 and 217 polling stations reporting no and only partial information respectively. The investigators traced the IVRS log file and confirmed with CTIL that this decrease in performance was due to the decrease in available cache memory (cache memory are resources required for the IVRS to perform calculation and/or database read/write actions).

CTIL reported that the patch applied at 5:00 pm might have caused this phenomenon. As the new call flow of skipping the “accumulative voter turnout view” somehow failed to release the working cache memory to the system for reuse, subsequent drop in the cache memory level caused the termination of the calls.

CTIL then devised a workaround for this situation by constantly monitor the cache memory level and triggered a system reboot right before every reporting period so that all cache memory would be released prior to the start of the last three reporting periods.

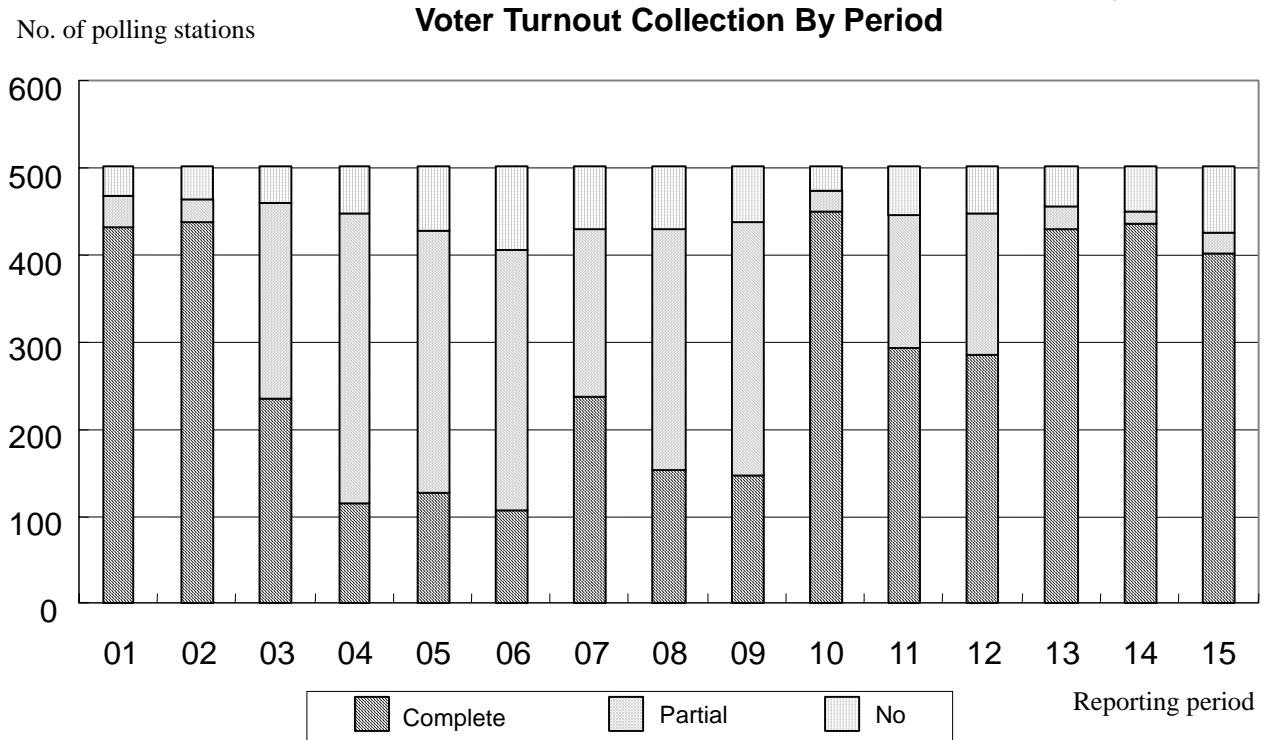
8:30 pm Preparation for the “Emergency Plan” was underway and the Technical Services Team had gathered additional staff to strengthen the IVRS Support Hotline and ready for the action after close of poll.

11:00 pm to 1:30 am (13/9) Staff from the IVRS Support Hotline called all 501 polling stations to collect voter turnout figures of the GC and all related FCs. The information collected was dispatched to CTIL in batches of 10 polling stations each.

1:30 am (13/9) to 6:30am (13/9) CTIL was responsible for the data entry and verification of the information collected by REO’s IVRS Support Hotline staff. A total of 16 CTIL staff members were deployed. They verified the data stored in the database against the collected data from REO. Should there be any discrepancies, the last period’s total would be adjusted to bring the cumulative total in line with the figure provided by REO’s IVRS Support Hotline.

In order to ensure the final result was accurate and that there were complicated steps to verify and backup the databases, the CTIL staff took more than 5 hours to complete processing the large amount of data involved.

3.2 The status of the voter turnout reporting of all 501 polling stations for all fifteen periods as recorded in the CTIL’s database on polling day is summarised in the graph below.



4. Findings of the investigation

4.1 The IVRS deployed by the REO on polling day was to perform four functions, namely reporting polling station opening time, reporting voter turnout figure, reporting complaint statistics and reporting counting results from various polling-cum-counting stations. The performance of the system for each function is summarised as follows:

Function	Performance
1. Polling station opening time reporting	Normal
2. Voter turnout figure reporting	Significant Failure
3. Complaint statistics reporting	Normal
4. Counting results reporting	Normal

4.2 The voter turnout figure reporting function had failed, and from the information we gathered and worked through, our findings are set out below.

A. Shortfall in the design and capacity of the system

4.3 CTIL confirmed that the root cause of the 100% constant CPU loading was a “*database view*” (a database view is a procedure used within the database to retrieve information) that was supposed to calculate and return the accumulative voter turnout figures for both GC and FCs of a specific polling station.

4.4 This particular “database view” was executed every time an incoming call was received. It was intended to calculate and report the accumulated voter turnout figures for all related GC and FC constituencies to the calling polling station. The actual design of the algorithm for the calculation was the cause of the problem because every time it calculated the accumulated voter turnout figure of the required constituency, it started from the very first period to the current reporting period.

Period	Calculating operation
1	Period 1
2	Period 1 + Period 2
3	Period 1 + Period 2 + Period 3
:	
14	Period 1 + Period 2 + + Period 13 + Period 14
15	Period 1 + Period 2 + + Period 14 + Period 15

4.5 The IVRS behaved normally for the first two periods, but as the data started to accumulate and with 501 polling stations calling in, and the system doing the same calculation for an increasing number of stations, this “database view” required longer duration to complete its operation. This increasing calculation time caused the CPU to be very busy and generated an

error in the interactive voice response servers (which handled all in-coming telephone calls) to disconnect the in-coming calls.

4.6 Such shortfall in the design revealed the fact that there were significant variances between the expected overall capacity of the developed system and the live production environment. The overall capacity of the IVRS comprised several major components including the capacity to handle simultaneous in-coming telephone calls, the capacity of network communications between the servers, and the capacity to compute and record transactions. We agree with the vendor that the first two elements were properly catered for. However, the shortfall in the database design seriously impaired the capacity and performance of the database server to retrieve records and perform calculation, which led to the significant failure of voter turnout reporting on polling day.

B. Deficiencies in the testing of the system

4.7 After reviewing the detailed approach of various kinds of system testing prior to live production on polling day, it was noticed that the test cases used in the simulation did not represent the true picture of the live situation.

4.8 From the report submitted by the CTIL on 20th September 2004, it mentioned:

“The design of the Stress testing sought to simulate maximum activity with high concurrent activity and high transaction rates, as this is the highest probable cause of failure for this type of system.”

We do agree and respect the expertise of CTIL in that the provision of

telephone lines played an important role, but we have strong reservation on the approach of the loading tests for the IVRS prior to live production. We discovered that the test cases to simulate the reporting process of each polling station consisted of voter turnout figures for one geographical constituency and one functional constituency only. This was far from the reality as we had on average one geographical constituency and around fourteen functional constituencies per polling station.

4.9 The number of functional constituencies required to be reported by each polling station was clearly stated in the user requirement. In designing the loading test of this kind, the CTIL should have taken into consideration the appropriateness of the testing case when compared with the actual scenario on polling day. Had the simulation in the loading test been more complete and reflected the actual input of each of these 501 polling stations, such a problem would have surfaced during the test and rectification could have been made prior to live production. On the end-user side, staff of the Technical Services Team only compared the testing concept of CTIL with that adopted by the vendor responsible for IVRS for the 2003 District Council Election, ie to test the capability of the system to handle 501 phone calls at the same time. As both vendors adopted the same concept, staff of the Technical Services Team were convinced that the test cases prepared by CTIL could already serve the purpose.

4.10 The arguments behind for the Technical Services Team to accept the testing concept adopted by CTIL were somewhat weak. The fact that the same testing concept was adopted by the vendor for the 2003 District Council Election does not necessarily mean the testing concept is in order. Should the same bug exist in the software used by the previous vendor, it would have also escaped detection by the test cases.

C. Inappropriate approach for the rehearsals for staff

4.11 Prior to the polling day of the 2004 LegCo Election, rehearsals were arranged for the PROs and DPROs to practise using the IVRS. There were altogether four rehearsals arranged, two for PROs (31st August and 7th September) and two for DPROs (30th August and 6th September).

4.12 We have gone through the audit trails that CTIL gave to REO's IVRS Team. The summary of the statistics is tabulated below:

	Total number of participants	Number of periods reported		
		1	2	3 or more
PRO	162	126 (77.8%)	24 (14.8%)	12 ⁱ (7.4%)
DPRO	254	166 (65.6%)	53 (20.9%)	35 ⁱⁱ (13.5%)

ⁱ The maximum number of periods reported is 9

ⁱⁱ The maximum number of periods reported is 8

4.13 We have noticed that most of the polling staff only tried to use the IVRS once during the rehearsal session and the number of concurrent access within the same reporting period by these polling staff was rather low. Throughout the whole rehearsal session, the maximum number of concurrent users for PRO was only 40 at period 2 on 7th September, and for DPRO was only 31 at period 2 on 30th August. The complete concurrent usage for all four rehearsals are listed in the tables below.

PRO Rehearsal – Concurrent Usage Statistics

Period \ Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
31 August	2	17	22	12	3	6	9	12	7	11	6	2	4	4	2
7 September	3	40	14	9	6	3	7	10	5	2	4	1	4	2	0

DPRO Rehearsal – Concurrent Usage Statistics

Period \ Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
30 August	4	31	30	21	21	7	24	23	24	12	6	6	3	7	9
6 September	3	29	22	27	20	5	12	9	17	12	9	2	5	4	4

4.14 The approach of the rehearsal session was not to have ALL participating polling officers to have hands-on experience with the IVRS, and based on the information supplied by the Technical Services Team and we quote:

“Objective of the Rehearsal Sessions

The main target of the rehearsal for PROs/DPROs was to provide an opportunity for polling staff to familiarise themselves with the functions of the IVRS. It was never intended to be used as a kind of testing on the IVRS. Unlike the mandatory Intensive Training Sessions for PROs/DPROs, participation in the IVRS rehearsal sessions were on voluntary basis. Meanwhile, all of the functions and call scripts were presented and demonstrated beforehand to PROs/DPROs during the Intensive Training Sessions.”

From the above, we conclude that these rehearsals were on a voluntary basis.

4.15 We understand the difficulty involved in arranging a “close-to-live” rehearsal simulating reports by all 501 stations over a 15 hour period. But we are strongly of the view that if this rehearsal had been arranged just like the compulsory training session for PROs and DPROs at a reduced number of periods, say three 1-hour periods, the same problematic scenario that appeared on polling day would have appeared and rectification could then be made prior to live production.

D. Ad-hoc contingency planning

4.16 For any information system there should be a corresponding contingency plan to backup the operation should any part of the developed system, either hardware or software or both, failed to function. Depending on the nature and criticality of the system, different types of contingencies are required.

4.17 For the IVRS being deployed on polling day, CTIL had adopted an approach of “100% redundancy” in designing the hardware contingency for all major servers (that is, an identical secondary machine would turn-on as standby and would take up the job of the primary server if it failed). This is a normal practice for on-line and real-time system that had to operate continuously. Testing in triggering the standby machines had also been made prior to live production and was proven to be successful.

4.18 However, one should never rule out the possibility of double failure on both primary and secondary machines, or the remote chance of software system failure due to unforeseen reason. While it is not practicable to put in place a large pool of staff in reserve for a full-scale manual-based

contingency plan, there should have been a more detailed contingency plan with a reasonable level of backup staff just in case there is a need of shifting part of the data collection to manual mode because of significant system failure. Nevertheless, such plan was not well defined and organised prior to the election and details were only formulated after the incident was reported on polling day.

4.19 From the IT project management point of view, CTIL being the developer ought to have pointed out to the REO about the risk involved when the developed system failed. On the end-user side, the related REO officer being the owner of the system should have been more aware of the above risks and worked with the vendor prior to live production to decide and design the type of manual-based contingency plan they required. Such a plan should be well defined in advance of the event and thoroughly discussed with the IT vendor on what the criteria in triggering the plan were and the escalation procedure involved.

4.20 The manual-based contingency plan improvised in the evening of 12 September might be the best available plan that could be drawn up within the very short time available. The staff of the Technical Services Team were also under considerable pressure on polling day and it is understandable that any contingency measures so drawn up were not very well thought-out. For example, more manpower from the REO could have been redeployed in the early morning of 13 September to augment the 16 CTIL staff members for data input and verification, thus shortening the time required to process the data so that the final voter turnout figures could be announced earlier. Should the responsible staff have addressed their minds on these contingency measures well in advance, the plan could be more thorough and well-organised.