Institution of Civil Engineering Surveyors

M92 CARRIAGEWAY RESURFACING AND JUNCTION INSTALLATION PROJECT

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EXPERIENCE REPORT

1.0 INTRODUCTION

1.1 Background

John P. Thompson is employed by ICES Land Surveys Ltd (ILS) as a Senior Land Surveyor and has undertaken this role since July 1999.

The role of this project (Feb-Jul 2002) also included the management and responsibility of 6 survey teams.

ILS was formed in 1970 and currently employs over 200 staff based out of five offices throughout the UK.

The company has evolved to include a broad spectrum of survey skills and now comprises four strategic business units: -

- Survey
- Civil Engineering
- Computer-aided design (CAD)
- Geographic information systems (GIS)

1.2 Confidentiality Statement

This critical analysis is subject to a confidentiality clause. Permission has been granted from both ILS and the Highways Agency to use material relating to the contract in this critical analysis. The information contained within shall not be passed to any third party or reproduced in any form whatsoever.

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2.0 PROJECT OVERVIEW

The initial brief, given by Highways Agency to ILS, was to undertake a topographic pre-works survey of the North and Southbound carriageways, Junctions 10 and 11 and 150m into the adjacent grass verge areas, on the M92 (refer to Appendix A). The survey was to be used as a design base by the Civil Engineering Department for future resurfacing works and the installation of spur road (Junction 10A).

Critical path analysis was the main planning method to show Highways Agency the intended timescales for project completion (Refer to Appendix B). This enabled the survey to be broken down into individual components to facilitate different tasks being operated simultaneously. The timings were based on similar motorway surveys undertaken in the past.

Initially, two teams of surveyors undertook the planimetric and level control network surveys. Once completed, three survey teams undertook detail work and one team focused on cross-sections. Using this method allowed teams to become relatively specialised in their allotted tasks, thus improving efficiency and reducing on-site time.

Due to the confidential nature of the company's financial arrangements with the Highways Agency, financial information cannot be disclosed to third parties. However, when pricing of the project, additional factors had to be incorporated into the pricing structure to allow for extraneous risk / cost implications. Such as investment in Leica TCRA professional tracking theodolites (being on their field trials for the first time), additional insurance and Personnel Protective Equipment (PPE) e.g. flashing LED vests (see figure 1).

Figure 1 - flashing LED vests

3.0 PROJECT AIMS AND OBJECTIVES

The scope of works included the following: -

- Establish survey control.
- Co-ordinate survey stations, tied into the existing M92 survey network.
- Levelling.
- Conventional ground survey and cross sections.
- Output to MOSS and AutoCAD.
- To complete the project within the contractual timeframe.

4.0 HEALTH AND SAFETY (H & S)

The extremely hazardous nature of motorway environments requires stringent H & S policies and practices. ILS had to meet all health and safety regulations and the Highways Agency own specifications.

ILS as part of their contractual obligations, identified, assessed and reported all risks to H & S prior to any project works commencing. (Refer to Appendix C).

The following H & S issues had to be accounted for prior to the project commencing:

- All personnel undertook and passed Highways Agency's H & S Induction Course.
- All appointed drivers passed the Highways Agency's Advanced Driving Course.
- Selected personnel had to undertake a Communications Course to liase with the M92 European Freight Terminal Operations Control (EFT)

The following issues were carried out on a daily or weekly basis:

- The collection of work permits from EFT.
- Informing EFT of work location so site safety officers could be arranged for our supervision.
- Providing daily H & S briefings in regard to the area of work and PPE involved prior to surveyors entering the survey site.
- Reiterating emergency communication numbers, contacts and procedures to all personnel.
- Ensuring "clean, clear and checked" site exit procedures were implemented prior to leaving site.

5.0 PLANIMETRIC CONTROL

5.1 PGM Establishment

Before commencing the installation of permanent ground markers (PGM's), assessments were undertaken to determine adequate saturation levels. These were governed by three main factors: -

- Risk free installation, in positions of safety and outside zones of influence.
- Levelling limits at night (approximately 30m maximum).
- Limit of 100m for reference observations, to achieve contractual accuracy.

During installation, PGM's were drilled and securely grouted in epoxy resin with final stability checks of the PGM's made prior to leaving site.

5.2 M92 / EFT Survey Network

While many different grid systems exist at around the M92 and EFT, one primary "M92 Grid" exists. The M92 Grid is required on all projects at on or associated with the M92. The M92 Grid is a plane "true to scale" grid orientated to Ordnance Survey (OS) Grid North and based on an OS Trig Point on the Control Centre at EFT.

5.3 Global Positioning System (GPS) v Total Station

In order to achieve an accurate network of PGM's two methods of traversing were assessed. Using theodolites was firstly considered but finally rejected. The concluding factors were based on the time to undertake the traverse relative to GPS work and the possible loss of absolute accuracy relative to any other PGM within the network. However the main consideration was the H & S implications (no unattended tripods could be left on the carriageways).

The GPS Control Survey was undertaken using two permanent and constantly used base stations to determine accurate base line fixing. These were constantly logged data sets on 5-second 5km baseline and recorded in WGS84 format.

During the control survey itself; three Leica Series 300 GPS satellite receivers were to be used in a leapfrog fashion to co-ordinate successive stations along the carriageways. The receivers 1 and 2 were set on 5-second 5 km recording data sets and were left for at least 5 minutes or 120% of the required time until the third receiver was set up. This leap-frogging process enabled each PGM to have overlapping data sets with adjacent PGM's and the two base stations thus provided a network of braced quadrilaterals. The received data sets were processed and adjusted using Leica's Ski Office Processing software to produce an absolute planimetric accuracy of ±3mm with any other PGM on the network.

6.0 HEIGHT CONTROL

Several instrument types for levelling were considered to establish accurate height control. It was eventually decided that a Leica NA 2000 digital level and invar staff would be the most suitable to meet contractual accuracy. Also the digital level would eliminate any errors from mis-booking, or mis-reading at night.

Digital levelling along the carriageway utilised a closed traverse loop between pre-determined heights on existing PGM's, sub-loops were made to PGM's adjacent to the carriageway to provide additional validation checks along the traverse route. Change points were on the 'new' PGM stations, this enabled backsight and foresight observations to be usually no more than 30 metres in length.

Unforeseen problems were encountered at night on the southern carriageway because of the digital levels' inability to cope with the intense background lighting that existed around the EFT Buildings. This reduced backsight and foresight distances to sub 15 metres. The problem was overcome by positioning the level so that the Invar staff appeared in an area of low intensity back light. Additionally, heavy-duty lighting was placed in front of the Invar staff so that the digital level could read the information.

The results of the levelling were deemed acceptable; the northern and southern carriageways had a misclosure value of <1mm over the 8Km-carriageway length. (Refer to Appendix D).

7.0 DETAIL SURVEY

7.1 Problems

In determining the best method of surveying to achieve the contractual planimetric accuracy of ±25mm, height accuracy of ±20mm soft and ±5mm hard. Four main problems needed to be overcome.

1) Sighting at night
2) Pogo height
3) Instrument height reading
4) No unattended tripods (solution - not used)

7.2 Option Assessment

Prior to survey commencement, ranges of survey methods were considered. Baseline, tacheometric surveys were first considered. Although possibly considered a more accurate form of positioning, this method could introduce too many errors into the survey observations. (Especially points 2) & 3) above, in windy conditions.) Also, having reference backsights at virtually 180 degrees to one another was not considered angularily accurate. This method would also require a greater PGM saturation rate to meet the level accuracy over the longer distances to the verge extents.

Real-time GPS surveying was also considered but had insufficient accuracy for hard detail levels. Additionally H & S requirements stated no person could work unattended on the M92 and EFT project and thus negated the benefit of using Real-time GPS.

It was decided that for the precise detail tacheometric surveying, trilateration methods would be employed. This "Freestation" method addressed the above height problems by utilising a fixed height pogo for both PGM references and detail / cross-section observations. The instrument collimation height being determined solely by the reference observations, eliminating points 2) & 3).

7.3 Instrumentation

A choice of total station instruments was considered, which could overcome point 1) The benefit of using TCRA's (see figure 2) over conventional total stations, was that during the night surveys, the instrument man only had to point the viewfinder in the approximate direction of the prism. The automatic target recognition (ATR) function accurately located and recorded the centre of the prism. This increased the speed and accuracy achieving approximately 1000 points / team / shift. The TCRA instruments were established and marked on the centre line of the carriageway, opposite a PGM. Multiple observations were taken (both faces) to mini-prism pogos on 2 or 3 PGM's (See Appendix E). Additional reference observations were taken to remote objects to enable regular angular checks to be made during the night without the need to revisit PGM's.

Figure 2 - TCRA on carriageway

The TCRA's also had an active tracking facility, which followed the prism and constantly updated the distance measurements, while the 'detail man' walked between survey points. The instrument man only needed to press the record button to take the observation. This increased observational rates up to 1500 points / team / shift increasing productivity by 50%.

Field coding for detail observations were carried out in a string format were points on a particular feature were picked up successively. Points were observed and validated by edge matching with observations from adjacent set-ups. A new multiple coding system enabled several linear features to be observed simultaneously, e.g. paint lines and "cat's eyes ". This considerably speeded up survey field time.

Symbol features were surveyed both in size and orientation. Each symbol was given its own feature code so later processing could facilitate the analysis of specific symbol types such as inspection chambers. At least 2 symbols were re-observed to ensure that adjacent surveys were within specified positional tolerances.

Quality control checks highlighted errors in the TCRA's tracking mode. Although the instrument correctly followed the prism and recording during rapid angular movements, real-time updates to the distances were not achieved. (The TCRA recorded the correct angles but not true distances.) The manufacturer was immediately informed of the problems and survey procedure reverted to ATR (which enabled improved performance over traditional survey instruments).

An upgrade to the TCRA software was released later, but surveyors took a while to regain confidence in using this function, because of the amount of rework needed previously.

8.0 CROSS-SECTIONS

A comprehensive level coverage of the site on a 25m x 5m grid for hard surfaces and 25m x 10m on soft surfaces was also needed as part of the contract with Highways Agency.

Two methods were considered. Firstly, setting out a predetermined grid and secondly, the marking out of the cross sections using a measuring wheel.

After consultation with the project engineers at Highways Agency, it was decided that the time taken to set out the grid points would not be worthwhile relative to the wheel measurement. The reasoning behind this was that the contours generated at the end of the survey would be used for interpolation of cross sections instead of using absolute points of true cross sections lines. In addition to this, survey juniors would require further training.

Before any cross-sections could commence, the 25 metre cross section reference points had to be setout on the outer edges of each carriageway. This provided an accurate perpendicular line for the 5-metre cross-section survey. In practice this method failed as surveyors found it difficult to trace the perpendicular line at night.

The solution involved using lights on the marks along the carriageway shoulders, with a third light on the carriageway centreline. Surveyors then used these reference lights to maintain the perpendicular lines while observing the cross-sections.

Figure 3 - surveying the cross-sections.

9.0 DIGITAL OUTPUT

9.1 Validation

Survey validation was necessary to prove the reliability of the data collected. (Refer to Appendix E). No processing could proceed until any errors and warnings highlighted in ILS validation software, were manually corrected for and approved by the surveyor in charge.

The validation summary highlighted errors that existed between field observations and calculated values. A scaling cut off limit that equated to a planimetric accuracy of ±7.5mm was adopted. A misclosure check proved the degree instrument movement during the interim period of establishing the initial control and the final observations. An accepted cut off limit was 15 seconds misclosure that equated to a 7.5mm error in plan per 100 metres. The combined error would then be within contractual tolerances.

9.2 Processing

Processing was done using a CAD drawing package, prior to AutoCAD and MOSS conversion. A set of specific data tables were developed for the Highways Agency CAD standards and are outlined in the confidential document 'Processing of Highways Agency work'. (Refer to Appendix F). Once all survey work was completed, processed, validated and graphically edited, weekly field inspections were made utilising provisional plots. Walk-through exercises were undertaken to ensure no omissions in survey fieldwork had occurred.

9.3 AutoCAD / MOSS Output

The Highways Agency uses an extensive and strict Geographic Information System for data, maintenance and design work. (Refer to Appendix G). Additionally, the Highways Agency required data in two formats, MOSS and AutoCAD. The project needed a comprehensive yet flexible coding system so that data collected could be easily converted to meet these requirements.

The main issue during processing was overcoming the problems of two separate output types: MOSS having levels as strings and symbols as points, AutoCAD having levels as text and symbols as polylines.

Prior to sending the final product additional checks ensured all field code information was correctly transferred to AutoCAD and MOSS. A validation record was produced upon transfer and highlighted any information that failed to be transferred. Occasionally, errors occurred during inappropriate use of field coding. Amendments were made to the feature code table and informing the Highways Agency through regular reviews of the feature code tables amendments. Sample DXF outputs were issued to the client on a regular basis so the Highways Agency could assess information being collected and perform their own field validation.

10.0 REFLECTIVE ANALYSIS OF PROJECT

In hindsight, it is easy to reflect on the issues and problems that occurred with the project. It is not always possible to exclude all factors, which may impede a projects progress to meet its deadlines. However, important lessons were learnt and will be implemented into the planning of future operations.

Access to the carriageways was unavailable at the time of assessment due to the strict H & S policies enforced at the time of scoping. The project was based on previous costing models of carriageway surveys. This assessment resulted in a costing model that correctly estimated the costs involved in levelling and PGM control. However, the number of cracks that existed in the tarmac of the older carriageway surfaces and redundant features could not be quantified. This coupled with Highways Agency's additional specification requirements during the survey resulted in the extension of project deadlines.

Further to completion of this project, costing models have been created specifically for the M92 interchange. In future, any further projects of this kind will utilise these base-costing models resulting in a more effective project assessment.

During the project, reviews with the Highways Agency had been conducted on a fortnightly basis. These meetings highlighted a necessity to increase the scope of the survey from that originally envisaged which resulted in deadlines being increased to accommodate additional work. It is advantageous of future projects to have a more rigorous briefing with clients prior to work commencement.

Management of surveyors included addressing motivational factors. Although initially assessed, the degree of night shift lethargy and the simplicity of Leica TCRA instruments (which required a lower level of input by the surveyor) resulted in a 'lower boredom threshold'. These problems were generally overcome through monthly staff rotation of tasks. With foresight, the frequency of rotation should have been increased to maintain staff motivation and morale.

A large degree of survey time was lost due to a variety of factors, which were beyond the control of the survey teams. These factors were generally a product of the intense H & S regime that exists on the M92 / EFT interchange. These downtime factors were acknowledged prior to the commencement of the project but the severity of these factors impacting on the delivery date was not fully appreciated. The use of additional survey teams at the time was considered, but would have compromised the efficiency of our safety arrangements and was therefore disregarded. In addition to this, the use of extra survey teams during down time would increase variable costs.

The use of additional survey teams on future projects with less stringent H & S issues could be considered to meet deadlines. Equilibrium has to be established which achieves speedier surveying without surveyors impeding each other's progress, while still maintaining product quality.

The H & S assessments proved to be excellent with zero incidents on site by ILS personnel. However, incidents occurred outside the company's H & S brief. In future, the duty of care of survey teams to acknowledge and report the H & S actions of third parties needs to be emphasised.

The use of GPS on the project in establishing PGM's proved to be more than adequate to achieve contract specifications. This resulted in a greater absolute planimetric accuracy of PGM's in relation to any other PGM on the airport. This method will be utilised in future for large projects because of the overall accuracy and speed obtained.

Digital levelling of the PGM's proved to be exceptional. However, increased testing of the equipment prior to survey would not have highlighted the NA2000 inability to cope with intense background lighting from EFT. The light intensity of the Terminal Building illumination could not have been simulated in a controlled and cost effective manner. This factor will be taken into account in future projects involving high intensity lights.

TCRA's field trials should have been conducted in 'real time' to assess if any faults were apparent prior to survey commencing. Although field tests were applied, a more rigorous approach should have been adopted to measure a specified number of points within a given time frame. Despite these facts, the investments in TCRA's considerably speeded up the survey time and proved invaluable.

In retrospect, managing the project at a survey level has provided a greater awareness of the responsibility associated with large-scale projects, thus improving my professional approach to surveying. Realistic scoping and effective planning are essential elements for any project to succeed. Management of physical and human resources to meet client expectations both in quality, quantity and value of output are paramount for client satisfaction and to maintain the reputability of the survey profession.

APPENDIX A SITE PLAN

APPENDIX B CRITICAL PATH ANALYSIS

APPENDIX C METHOD STATEMENT AND RISK ASSESSMENT

APPENDIX D LEVELLING ADJUSTMENT SUMMARY

APPENDIX E SET UP VALIDATION SUMMARY

APPENDIX F CAD CONVENTIONS

APPENDIX G LAND SURVEY FRAMEWORK SPECIFICATION