‘Safety in Numbers’: Calculation and Document Re-Use in Knowledge Work

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ABSTRACT
This paper presents detailed examples of document use and re-use, through an ethnographic study of the knowledge work associated with road safety audit in a civil engineering consultancy The paper incorporates some detailed observation of practices, conversations, and other activities occurring around document re-use in everyday work. It outlines some aspects of the everyday use and re-use of engineering documents in the practical accomplishment of everyday knowledge work as the first stage in considering how these activities can be technologically supported.

Keywords
Ethnography; Knowledge Work; Document Use.

INTRODUCTION
Research into information-use has generally focused on the technical and mechanical aspects of information systems and has predominately been interested in depicting the flow and structures of data and producing designs that are amenable to technical solutions. Essentially, this research has relied on a view of information use as predictable and rational, with each logically defined element studied and understood in isolation. This has permitted the technical and mechanical elements of information systems to be considered separately and meant, as a consequence, that the human element has been largely ignored. Both the focused concentration on the technical elements of information systems and the information processing depictions of information use are coming under increasing criticism in the document management and information systems literature. In particular, with the increasing interest and attention paid to various forms of knowledge work, information use has been observed to be highly unpredictable and to result from needs that are often implicit or ambiguous. These information needs are seen not as static, but as formed and reconstructed as people take part in their day-to-day activities. Work, and knowledge work in particular, has begun to be recognised as highly situated in nature [14].

The study presented here aims to orient information systems research so these considerations might be better understood and so that information mechanisms might be designed to meet people’s information needs. To make sense of the complexities of people’s information needs, the study seeks to explore the nature of information use in situ by looking at the knowledge work performed in specific contexts. The premise is that through these investigations, information retrieval, extraction and re-mastering systems might be designed that operate in concert with people’s changing and evolving information needs.

This paper presents a number of detailed examples of document use and re-use, and their interrelation, drawn from a brief ‘quick and dirty’ ethnographic study [8] of work in a civil engineering consultancy dealing with road safety audit. Although very brief, the study incorporates some detailed observation of practices, conversations, and other activities occurring in the fieldwork site and documents some aspects of the everyday use and re-use of engineering documents - mainly road plans and report templates - in the practical accomplishment of everyday work.

There has long been an interest in document use document creation, and record keeping [6; 7; 12; 10]. This paper investigates the ways in which professionals - specifically Civil Engineers - re-use or re-purpose their documents. It is concerned with the value different kinds of documents provide for different professionals, especially the intellectual content professionals take from the documents they use, the parts of documents that provide such value and how those elements of documents are re-used, an understanding of these issues being an essential first stage in the development of requirements for supporting technologies. The ethnographic study highlights document *re-use* with respect to a number of interrelated activities - in particular it stresses the use of templates as a guide for the preparation of road safety audit reports and the frequent use and annotation of surveyors plans as the locus for everyday work - both individual work and in the collaborative accomplishment of teamwork. As in other instances of

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document use [4] the annotation of plans is implicated in facilitating 'awareness' of various kinds; making the nature of work activities 'visible' and 'observable/reportable' to others connected to the work. Such awareness is an essential ingredient in working as part of a socially distributed division of labour.

The main focus is on what might be termed 'operational documents' - that is documents that are frequently consulted in the course of everyday work, as opposed to 'strategic documents' such as the standards documents that form the organisational and legal framework for the work. The role of documents in everyday work varied with the report templates acting to define and shape process, and as part of quality/audit trail, while the road plans were used for calculation, annotation and practice. The road plans were a working document and the focus for a great deal of collaborative activity, being used for checking purposes and for documenting the process of marshalling information. Finally, road plans were very often the locus for various kinds of analysis and diagnosis and the working out of possible design solutions. The main elements or types of re-use noted included: the re-use of format where the document formed part of a quality audit; and the re-use of content where the document was the focus of calculation work of various kinds. In addition, there was the re-use of process attesting to the way in which the whole of the road safety audit is based around several notions of process - the process by which road schemes get approved and the requirements for approval; and the process whereby roads and their associated features such as junctions and roundabouts are built.

ROAD SAFETY AUDIT: FIELDWORK OBSERVATIONS

The general regime of road safety audit is outlined and controlled by a set of regulatory documents adapted from those issued by the UK Dept of Transport and the Institute of Highway Engineers, and originally used when personnel were still working within the local County Council. Road safety audit takes place as a three stage process: an 'in principle' stage where the general design is checked 'against reality' and recommendations made; a 'before tender' stage when the full design is available for checking; and the final stage when the road is built and the civil engineers will go on site with various representatives. The engineers are interested in whether, and how, the road design contributes to, and ensures, the safety of various categories of road user. This is done by checking such things as road widths and curvatures; possible road speeds; the viewpoint of the road user at various locations such as junctions and roundabouts, and so on.

One of the major instantiations of document re-use is in the form of document templates and attachments for the various stages of the audit. There are three different formats for reports. Within the template the main body of the text will change each time. Also attached will be plans to identify location, design plans, safety comments and an audit team statement. The report also has section for 'accreditation - where people have to confirm they've received the report along with an 'initial letter' and a form of 'agreement' - confirmation of acceptance (for example. by the County Council). Each report has a unique project number, based on the district, how the project was funded and the date.

*"Once the project is set up … we only have two pieces of paper… the simplest one (*shows report*) has a statement of Intent, that's one piece of paper, drawings, plans, photos, a response sheet) ... and for anybody outside of this (team) ... there's a simplified quality plan to follow progress of process ... it's a project control checklist .. then there's the base reference docs ... that is to do X you need Y docs ... and there's a verification section ... to check output is in the form and standard you're happy with and retention of records is acceptable … and then the boss signs it off…"*

There are usually around three or four safety audits required at any one time on a fairly predictable basis and the team is likely to get advanced warning of any large projects. On the day of these observations the road safety audit team had eight safety audits in progress. The simplified fieldwork transcript below documents some observed features of a safety audit at an early design stage. In this case it is concerned with the proposed road system to service a new Business Park. The engineer in this instance is interested not only with the design and safety features of the proposed new roads and roundabouts but also how these compare and mesh with the existing road system. (Roundabouts are common in the UK for controlling traffic at road junctions instead of using traffic signals.) Document use and re-use here consists of the more or less constant examination and checking of plans, the use of a calculator and a ruler to look at road lengths, road sizes and curves, and the various provisions for pedestrian and other traffic. As he considers each part of the scheme and the various inter-relationships between the different parts, the engineer is engaged in a more or less constant process of scrutiny, calculation and annotation. Mainly through working on the horizontal plan, but occasionally by employing the vertical plan or design checklists, the engineer is involved in drawing the lines of the curves at roundabouts; shading in the pedestrian and cycle-path areas on the map; plotting the dips and crests in the road; and calculating possible road speeds. In this fashion the engineer identifies potential safety features to be examined in more detail when he goes out on a site visit.

Simplified transcript:

1. (Gets plan and puts it on his desk) *". this is an unusual one .. its very large .. equivalent to a bypass scheme - there's been a whole process behind this at county council level ..."* - (shows plan of proposed Business Park - on an old airfield site. He has been asked to have a general look at them – *"... at this stage we're trying to assess what we've got .. I've had a quick look .. its wanting in some areas ... the easiest thing to do is ... to produce a quick list of areas where … (the plan is) ... not well defined and there are obvious problems ... then*

chuck it back at the designers ... and suggest that they alter it before we do a formal audit ... "

2. (Looking at plans)(pointing at road*) " ... what's missing (is) ... no statement of design standards .. what speed vehicles are (supposed to be) moving.."*
3. (Looking at plans)(pointing at road*) ".. they've tried to minimise the size of junctions ...*" (to give themselves more land for building) – *" .. the roundabouts are smaller than the ones that already exist.."*
4. Explains the design problem of other road users - cyclists and pedestrians – who need to be ensured sensible routes and safe crossing points, and how this impacts on his safety *audit " .. so all sorts of things will be in my mind about it .. I already know what cycle facilities are .. on main route .. but how that ties up here is not clear.."*
5. (gets another plan out - cross section of road*) ".. that's interesting* (re: road size .. shows cross section*) - they have a margin for all the BT* (Telecommunications cables*) .. they won't get that in there .. 12 metres to play with from the back of the kerb .. to include footpath, cycleway and verge area.."*

In this next set of observations, the engineer is especially concerned with the proposed roundabouts, their size, the approach roads to them, their curvature and the camber of the road. The general issue here – apparent from a cursory look at the plans – is the clash between safety and economics. Small roundabouts release more land for development but have safety implications in that they may not reduce traffic speed sufficiently. Again these instances of document use involve the use of, and calculation and annotation on, the horizontal road plans. As he examines each of the roundabouts the engineer works on the plans, drawing on approach curves, shading in areas, aligning his pen with the approach and checking his calculations against a design table on road speed.

Simplified fieldwork transcript:

1. (looking at roundabout Number 6 on plan - talking about roundabouts - drivers have to be able to see the roundabout at a reasonable distance - so drivers can alter behaviour - to reduce speed - does geometric check - gets out design manual - easiest route around the roundabout and speed at entry should have radius of less than 100m)
2. (talking about drawing) *"... there's no way they can see their exit ... it suggests that somebody has tried to get a more sharp radius on entry and then forced it to fit the criteria ... so I'm a bit suspicious ... it starts a few alarm bells ringing ... need to go out and look at it ..."*
3. (explains problem re: size of r/about and camber on road and r/about ... chat re: problems of drainage)
4. (looking at roundabout 8) - gets ruler - *..." drawings don't give an easy picture ..."* - using ruler - 7 metre width - not particularly wide - talks about 'potential conflict of interest' on drawing - needs to check criteria of roundabout and approach to roundabout.
5. (looking at r/about) *"... oh dear ... they're going to attempt a long curve around the roundabout ... adverse camber .. is'nt too clever for one of this size ..."*
6. (looking at roundabout 8*) "... oh nasty ... he hasn't helped himself ..."* (puts pen down along line of approach road*) " ... driver coming to the roundabout will be looking the wrong way ..."*
7. (looking at roundabout 9) *"... oh yes the dual carriageway .. now here's an interesting thing."* - (using ruler) *"... oh dear we have a 7.6m carriageway on this side and a 7.1m carriageway that side ... there's a horrendous reverse camber for it ... the offside lane is completely unmanageable ..."*
8. (looking at longitudinal sections) *"...they've got a curve up there* (pointing*) ... crest here* (pointing) *... there are criteria for crest curves depending on the speed of the road ... we don't know the speed of the road ... normally for one of this standard you'd expect 70kph ..."*
9. (checking table design speed against horizontal radius and vertical curvature - tells what stopping distance is needed - looking at speed - speed is significant at the approach to a roundabout) *"...let's be kind and assume they've been allowed to design for 50kph ... let's check they've got the visibility."*
10. (using ruler to measure visibility) *"... supposed to see the roundabout from 105 metres ... but if speeds are higher this crest could come into play ... it's a point to bear in mind ..."*

TRAFFIC ACCIDENT AUDIT

Another aspect of road safety audit is termed traffic accident audit. This is involved with the identification and investigation of accident 'blackspots', and the design, costing and recommendation of possible road safety improvements. The key documents in this process include various accident reports, the horizontal and vertical road plans and the folders relating to particular road schemes. The documents are used in various ways. Accident report documents are used for devising different representations of the basic information as part of 'building a picture' of road safety features preliminary to design and implementation of modification and construction. The different road plans are used for calculation are heavily annotated and used for working out preliminary ideas. As the focus for collaborative, team activity, the plans are used as part of the process of analysis and for collation, checking and documentation purposes.

Traffic Accident Audit and Response: Fieldwork Observations

These observations covered part of a session where the engineer was interested in an aspect of a Traffic Accident Audit and Response. This process begins with a perusal of the Hazardous Sites Report, a document that lists 'hazardous sites' - where there have been six or more accidents in last three years - and which is then used to generate road safety 'schemes'. The engineer observed has responsibility for the 'Four Rivers' area and was currently looking at a major road. From the file he extracted a number of reports. The 1998 report identifies four hazardous sites on the road. The 1999 report similarly identifies four sites on same road and consequently, the Traffic Accident Audit is to be looked at as a 'route study' - that is, looking at safety and improvements to a whole stretch of a road rather than merely treating particular accident black spots.

The route study begins with the engineer finding a plan of the road and spreading it out on the desk. He's interested in long stretch of the road from the junction with the motorway up to 'Station Roundabout' - a route that consists of several potentially dangerous sites. Next he looks at a file containing confidential police accident reports that gives details of 49 accidents on the route in the past three years. The point of studying these accident statistics and reports is to transform the data presented through the drawing up of 'bubble diagrams' (see Figure 1). The 'bubbles' incorporate the accident reference number; the year (identified by colour); an abbreviation to give an indication of the severity of the accident based on injury (e.g. SLT= 'slight'); an indication of the road surface, time of day and weather conditions; and finally a small diagram of how the 'conflict' (traffic accident) occurred.

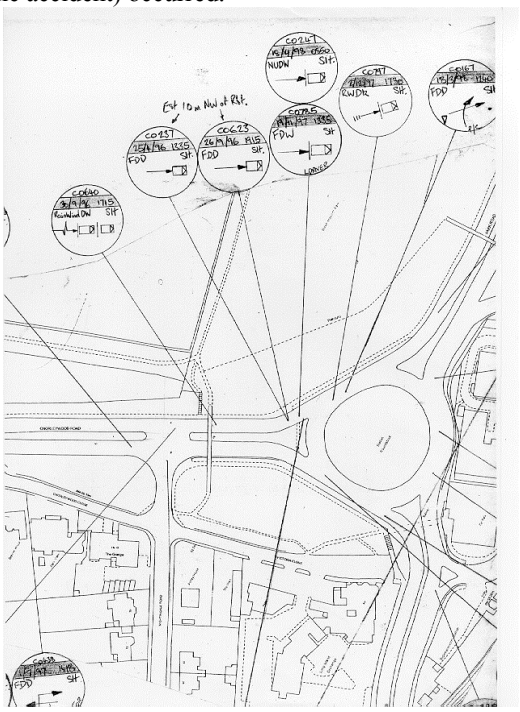


Figure 1: The 'bubble diagram'.

The accident 'bubbles' are then placed on the plan of the road to help the engineer 'build up pictures' - or patterns of specific problems that they can then focus on. A software package – 'key accidents' - has the facility to read the accident short reports and automatically generate the requisite 'bubbles' but the engineers generally believe in the benefit of doing this manually *"... as you go through it ... you're building up a picture in your mind ..."*

Another way of investigating accidents and thus another way of 'building up a picture' is provided through the Accident Investigation Sheet – in particular, the Accident Factor Grid (see Figure 2) and Analysis by Time (see Figure 3).

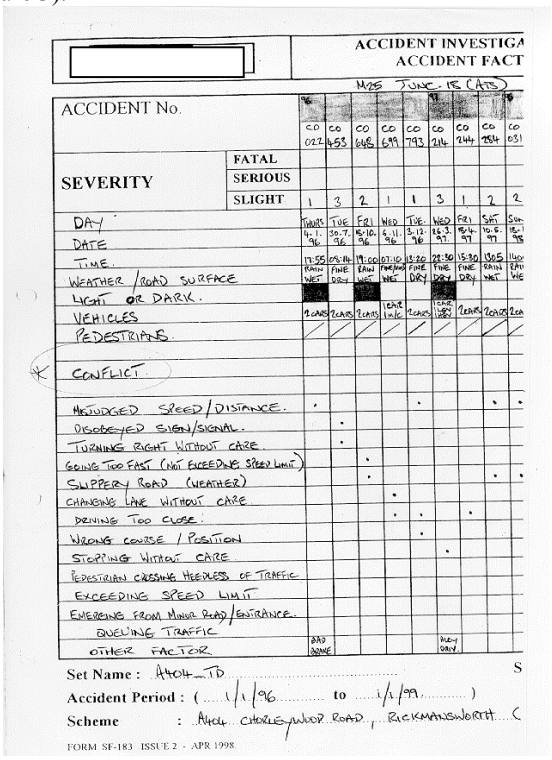


Figure 2: Accident Factor Grid.

These are both examples of information transformation, providing different ways of showing the accident information with the proposed aim of identifying common trends or themes not readily apparent from the bubble diagrams. This might involve, for example, looking for whether there are more accidents on a certain day, such as market day, whether the accident occurred in the light or the dark and thus whether they need to consider the existing street lighting, and so on. Yet another way of investigating a road traffic accident more thoroughly that is sometimes used by the engineers is to look at the original police report, including such things as the witness statements.

Whilst these might not necessarily reveal anything new the fact that they have been consulted forms part of an audit trail, or as one engineer stated*; "... they're not always going to tell me something I do not know ... but (then I) can't be criticised for not investigating as thoroughly as possible."*

The summary accident report is deemed useful because it: *".. tells things like where people people come from - (whether) familiar with area (and on autopilot) or not ... if nothing else it can confirm some of the details you're not sure of ... (but) ... a lot of the time you can't rely on the info ... there are discrepancies and its not as consistent as I'd like it to be ..."* Once this stage of the investigation is completed, the next step is to go out and conduct a site investigation. Again the idea here is the requirement to; *"... have picture in your mind ... what areas I need to look at ... what junctions."*

Simplified fieldwork extract:

(Looking at plan) *"... if you look* .(pointing at T junctions on the road plan). *we've got 3 T junctions here ... quite close to each other ... and when you look at the accidents they've got similar problems* (showing buuble diagram) *... involving vehicles on the carriageway .. of a similar nature ... shunt accidents ... car on main road waiting to turn and shunt accident occurs ..."*

"... the thing I'm looking at ... what's causing the accidents ... is there any way we can accommodate these stationary vehicles in the road ... can we give them a right turn lane for example.."

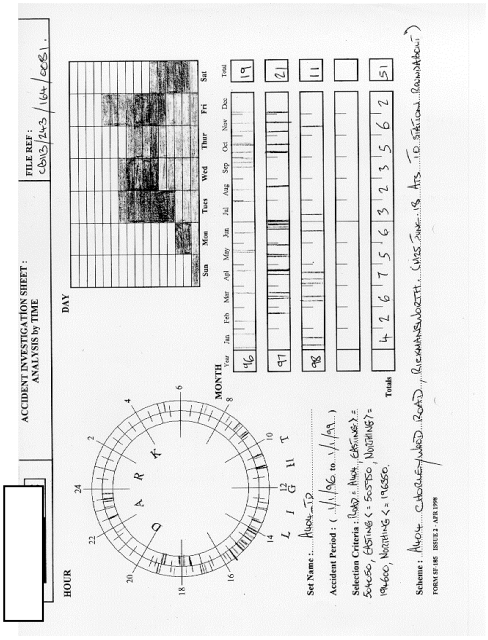
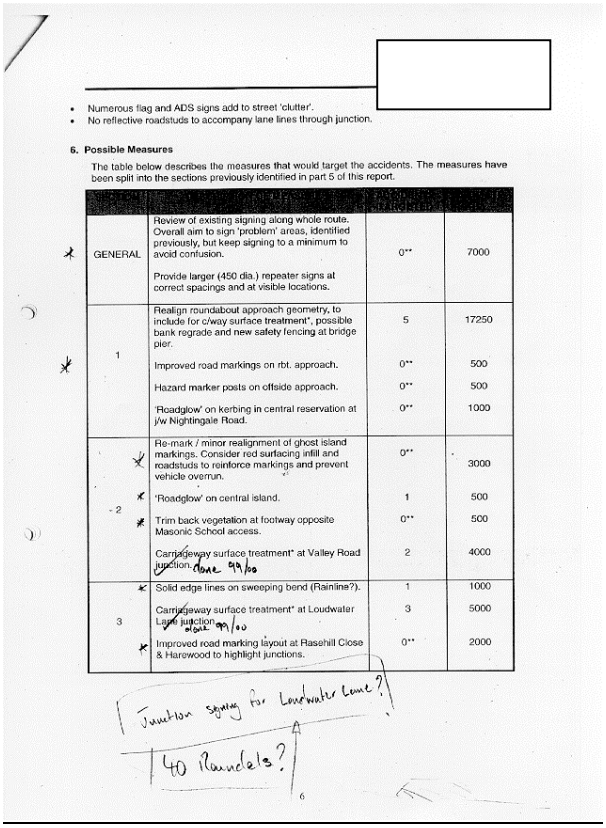


Figure 3: Analysis by Time.

Any possible solutions are dependent on what road span is currently available given that the purchase of land is not an available option . The schemes also have to be economically viable, that is they are required to demonstrate that they have saved a certain number of accidents and achieve a first year rate of return. Thus the final report (Figure 4) will contain a number of possible recommended measures with cost savings concluding with two possible figures for 'Predicted Accident Savings': an 'optimistic' prediction based on 'saving' 24 accidents over 3 years, and a 'pessimistic' prediction based on saving 12 accidents over 3 years.


- Numerous flag and ADS signs add to street 'clutter'.
- No reflective roadstuds to accompany lane lines through junction.

6. Possible Measures

The table below describes the measures that would target the accidents. The measures have been split into the sections previously identified in part 5 of this report.

✗	GENERAL	Review of existing signing along whole route. Overall aim to sign 'problem' areas, identified previously, but keep signing to a minimum to avoid confusion. Provide larger (450 dia.) repeater signs at correct spacings and at visible locations.	0**	7000
✗	1	Realign roundabout approach geometry, to include for c/way surface treatment*, possible bank regrade and new safety fencing at bridge pier.	5	17250
		Improved road markings on rbt. approach.	0**	500
		Hazard marker posts on offside approach.	0**	500
		'Roadglow' on kerbing in central reservation at j/w Nightingale Road.	0**	1000
✗	-2	Re-mark / minor realignment of ghost island markings. Consider red surfacing infill and roadstuds to reinforce markings and prevent vehicle overrun.	0**	3000
✗		'Roadglow' on central island.	1	500
✗		Trim back vegetation at footway opposite Masonic School access.	0**	500
		Carriageway surface treatment* at Valley Road junction. done 99/00	2	4000
✗	3	Solid edge lines on sweeping bend (Rainline?).	1	1000
		Carriageway surface treatment* at Loudwater Lane junction. done 99/00	3	5000
✗		Improved road marking layout at Rasehill Close & Harewood to highlight junctions.	0**	2000

Junction signing for Loudwater Lane?

40 Roundels?

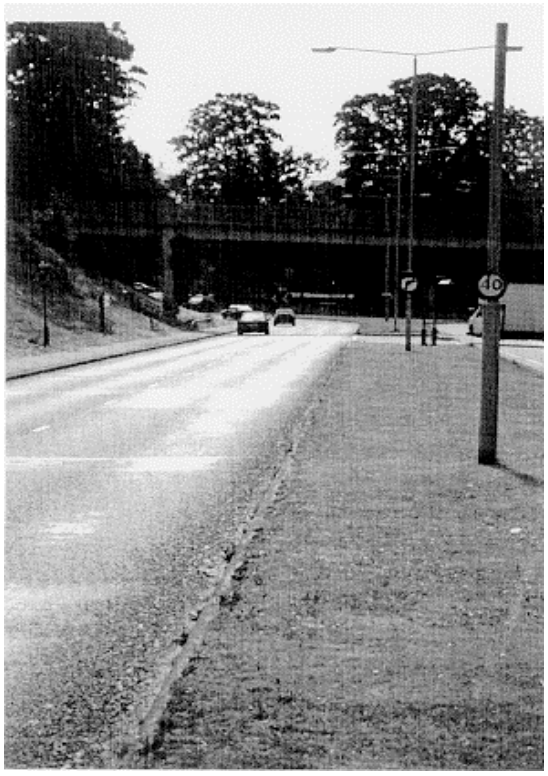
Figure 4: Final Report and Recommendations.

The 'first year economic rate of return' is also stated, based on calculations taken from the County Council Road Safety Plan where this type of approach (i.e., route action) is expected to produce a 175% return. The first year rate of return (FYRR) is then the product of a cost benefit analysis where the major number is the average cost of an injury/accident - currently some £79,000 – which, in turn, is obtained from the Department of Transport Highways Economic Note (HEN) 1. This particular route has already been the subject of some preliminary work.

Simplified fieldwork extract:

"We've actually done some work on this already ... we've done the easy bits ... easier bits last year ... what we did ... (pointing at road plan) *we resurfaced the approaches to these junctions ... and a new road layout that gives right turn vehicles some protection and highlights the junction ... here ...* (pointing*) ... they're coming screaming off the motorway on auto-pilot ... this is a 40mph road ... we've put a different coloured surface* (that makes a noise) *and we've done the hatching ... useful for high areas of skidding or braking ..."*

The focus of this particular day's work was a concern with accidents on the approach to the roundabout at one end of the route (see photograph). The 'bubble' (see Figure 1) and the accident analysis had revealed a number of 'shunt' accidents at the roundabout apparently (and typically) caused by the angle of the approach to the roundabout – whereby the drivers on the approach road would be turning their heads at such an angle to see traffic coming around the roundabout that they would be unaware of the position of the car in front of them on the approach. This had been confirmed by a visit to the site and the discovery of skidding marks, kerb strikes and accumulated debris (such as indicator glass) in the offside lane.



Photograph of site.

Simplified fieldwork extract:

1. *"... it's a short length of dual carriageway (gets photos) ... got a pattern here .look (pointing at bubble diagram) ... these ... they're all shunt accidents at the approach to the roundabout ... I'll go out there and think ... how is the road environment contributing to these accidents (gets survey plan of road) ... I've noticed that the approach (pointing) ... got a shallow entry angle ... the entry radius should be at the give way lines ... what I'm trying to do ... is ... move the road over effectively ... so that we've got the entry radius at the give way lines and they're coming in at a different angle ..."*
2. *"These are the notes I've made* (from visit to site*) ... dead area on nearside (rubbish) kerb strikes on offside ... gives us a clue ... broken indicator glass ... carriageway surfacing ... appears polished ... it suggests that skidding resistance is not up to it."*
3. *"... unfortunately things aren't as simple as moving the road over ... there's a fair amount of work in achieving an acceptable design ... got to marry up the changes so I don't create new problems like areas of 'ponding' ... where I'm trying to tie in the kerb line is in an area where there's an existing drainage problem ..."*

Coming up with a solution to the problem is not straightforward, however, since any alteration to the road – that is, in this case, effectively shifting it to the right – has repercussions that need to be investigated. One obvious concern is the problem that 'shifting the road to the right' may create new safety problems in the form of 'ponding' – creating areas of standing water on the road. An additional problem is that, as part of the general improvement scheme, there is a desire to protect a bridge over the road on the approach to the roundabout, from being hit and damaged in an accident. This is made difficult by the proximity of some steps that makes the erection of a safety barrier impossible and suggests therefore the use of a wider and higher type of kerbstone (see Figure 5).

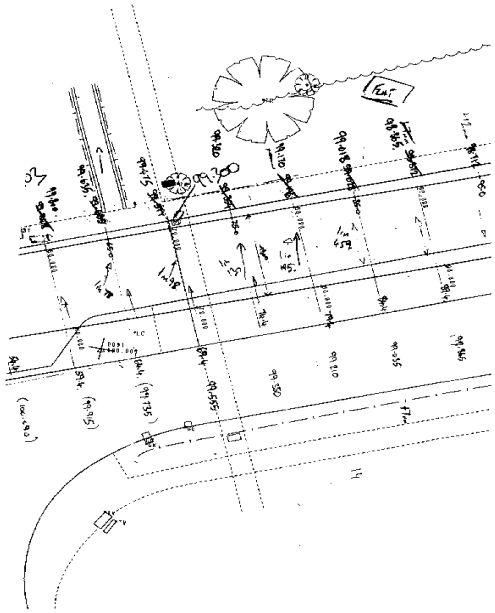


Figure 5: Plan of dual carriageway near bridge: the shift of the road to the right is marked; the BT box is marked on the lefthand-side; the arrows show the direction of the drainage and the 'flip-over'; the annotations show the results of working to alter the crossfall.

Simplified fieldwork extract:

1. (looking at survey plan and photos) *"... if we're going to do this we're opening up a can of worms ... this bridge pier* (pointing at plan) *... (is) ... protected by safety barrier ... but that length of fencing* (pointing) *is*

inadequate ... not far enough in advance for vehicles ... it's connected to wooden posts that have rotted away ... if anything left the road it would go into the pier ... we want to improve that as part of the works ... (but its) not straightforward ... there's the problem of these steps (pointing next to bridge) *... this is what we find ... it's never straightforward ..."*

Such a solution may, however, create other problems. Unfortunately, a BT communications box situated at the kerbside of the existing road complicates matters further since the new style kerb with its extra width may affect it.

Simplified fieldwork extract:

1. (explains re: BT box - pointing at plan) *"... with new kerb width wider ... this affects alignment of the road ... (but we're) not to affect that box* (pointing) *... cost of moving that would be 100s of thousands ... first year rate of return would not be viable ... so that's basically a fixed point ... whatever we do down there* (pointing at roundabout on plan) *"... we have to have this in mind back here* (pointing at plan) *... we have to design with this in mind."*

In this next set of observations the engineer is concerned with the issue of drainage. As already stated, moving the approach road to the right will impact on drainage possibly creating areas of 'ponding' (and therefore a safety hazard) near to the roundabout where cars are braking. The solution to this comes in the form of changing the direction of the drainage on the approach to the roundabout so that the water flows in the opposite direction, thus avoiding any 'ponding'. However, this needs to be done carefully as it also affects the gradient and camber of the road, and consequently the likely speed of traffic as it approaches the roundabout. Again this is not a simple task. Ensuring that the gradient at the roundabout is relatively shallow requires that the change of direction (the crossfall and flip-over) and the 'flatspot' and crest in the road should occur some distance away. However, the position of the bridge has to be taken into account – in particular, that any adjustment in the road to effect the crossfall does not alter the height of the road under the bridge.

Simplified fieldwork transcript:

1. *"I've only looked at it in the horizontal plane ... the vertical plane is where I'm at at the moment ... it's going downhill towards the roundabout and the road drains …* (shows crossfall) - *across the road. At the roundabout itself I've got a few fixed points ... I want to affect as little of the roundabout as I can ... I want to tie my design into what's there at the moment with as little fuss as possible ... I have to design-out any areas of ponding ... to get it to drain safely ... don't want areas of standing water where people are braking."*
2. (gets long section of drainage channels - doing line of new road alignment (looking at chainage points) *"... there's a problem with the scale of the drawings (1:20 versus 1:200) ... so what I've had to do is* (gets more plans) *use graph paper and plot them by hand ... doubled the size (1:10; 1:100) ... what I'm trying to do is get something that's acceptable … what was drawn on here (1:20) I've plotted on here (1:10) ... but it won't work ... so I've had to go back .. I've taken the levels of those ... plotted them onto here* (graph) *and then* (plan) *work out how they would actually work ..."*
3. *"I've worked out proposed levels for each chainage to find out if my first attempt is any good ... it needs changing ... it's far too shallow ... so I need to go back to the drawing board ... what I'm looking for ... looking to get the change in a 60 metre length ... but it's taking place too gradually ... too near to the roundabout ... I'm looking at the rate of change ... to make sure the gradient is within acceptable limits ... so that when you drive it .., it doesn't happen too quickly* (looking at notes – 'plot new n/side levels') *... what I've got to do is plot new nearside .. check the flip-over."* (where the drainage switches sides) (looking at notes – 'plot new n/side levels' - looking at graph and long-section plans)
4. (gets surveyors plan - puts on top of graphs - using ruler - moving between plan and graph plotting levels) *"... I'm going to go through each one of these and plot them onto that* (pointing at graph) *and* (pointing at plan) *and then go through the process again of plotting cross-falls ... and then I'll ask Alan ..."*

The difficulties associated with moving the road a little to the right to adjust the angle of approach to the roundabout are further complicated by the existence of a 12 inch gas main underneath the section of ground that will be required for the new portion of road. Unfortunately, there is no detail of precisely at what depth the main is at and this occasions further enquiry and decision making.

Simplified fieldwork extract:

1. (back to graph - looking at notes – hand written after previous talk with Alan*) "... we've also found ... as well as the cable TV box ... we've got a gas main ... 12 inch .. across the road ... it could affect the design ... I know the line of it and where it is roughly ... what I don't know for sure is what depth its at ... if its too shallow it could be a problem ... if we start putting traffic over this gas main it could fracture* (shows plans from Gas Co) – *"this is one of the first things we do with our schemes ... once a site has been identified ... that is probably the first thing you should do ... water, electricity, communications ..."*
2. (Looking at notes - record note of telephone conversation, site meeting to establish depth of 12 inch main, looks at fax of where main drains are, note of meeting with soils and materials engineer - note of sort of new carriageway construction they might be looking at.)

The engineer works on the plan, annotating it and plotting the nearside fall against the chainage, using his ruler and putting the newly calculated figures on the surveyors plan. This continues for some time but such plans are also the focus for considerable collaborative work and teamwork.
Simplified fieldwork extract:

1. *"I'm going to have a word with Alan ... I thought we were changing the levels here* (points at roundabout) *but we don't seem to be doing that."* (gets graphs and plans and notes.)
2. (with Alan - going through notes - plans) *"... what I've found ... this* (graph) *is the nearside ..* (pointing) *... this is the bit further back ... we've dropped this down* (gets another graph) *...there's no change here ..."*

Alan: *"... we've already adjusted this as much as we could ... your transition point* (points where the drainage direction changes) *is now further up the hill ... then you need to look at your offside alignment ... that's it ... those levels* (pointing) *are going to remain the same ..."*

Anthony: *"... what I didn't understand ... down here* (plan) *what was this?"* (pointing)

Alan: (looking at plan) *"... we had altered the levels earlier ... you've tinkered with the levels on this side* (pointing) *... this still might not work but that's as far as we can move the gully back before it starts interfering with people ... and becomes a maintenance problem."*

Anthony: *"... if it wobbles up and down too much its going to look awful ..."*

Alan: *"... quickly check what the crossfalls are doing in that area ... you don't want to muck about with that cross-over ...* (pointing) *the area where you want to do something with the changeover is here ...* (points) (Alan gets paper and draws diagram of road changes) *... make the changes gradual because this is going to look very odd."*

Alan: *"... the only thing that occurs to me ... you'll have to be careful about clearance ... because of the bridge* (pointing at plan) *... as long as you're not above the level of (existing) central reserve ... tops of the kerb need to be checked against the central reserve level ...* (Alan looks at plan ... does a drawing) *... that's another constraint you want to work to ... you can tinker with the levels beyond that structure* (points at bridge on plan) (looking at graph - holds up to eye and looks along the line) *... you'll want to raise the levels to move the flat point up the hill."*

Anthony: (gets notes ... reads out what he is supposed to be doing)

Alan: *"... keep tweaking the long sections and check the crossfalls ... then check they aren't digging up any of the road .'. don't try and think too many steps ahead cos you wont be able to do it ... try and break it down into small stages ...* (pointing) *... it's this area here you're going to have to change the offside levels* (gives Anthony calculator and ruler)

Anthony using calculator (shaking head) "*... at the moment that's very flat there."* (pointing)

CONCLUSION: DOCUMENTS AND DOCUMENT RE-USE.

Design as critique, ... implies acknowledging both the dangers and the opportunities that formal tools might entail. No longer denouncing tool or practice, it means searching for ways in which such tools may become familiar yet never totally transparent, powerful yet fragile instruments of change." [1]

The work of the civil engineers in road safety audit confirms previous findings on the importance of documents and document work in everyday, routine work. Thus, and for example, a regularly noted feature of working with plans in road safety audit was the preparatory work involved that took the form of various the 'transformations' of information obtained from one document, such as the police accident report, into another such as the 'bubble' diagram - re-representing the same information. We can see in the work of the civil engineers that the accident reports, the bubble diagrams, the accident factor analysis and so on, and documents that accompany them form a corpus of material with which to arrive at an accountable formulation. They constitute a 'repository' wherein: *"Ordered 'piles' of objects (are) indexed in a standardised fashion. Repositories are built to deal with problems of heterogeneity caused by different units of analysis. (They) have the advantage of modularity. People from different worlds can use or borrow from the 'pile' for their own purposes without having directly to negotiate differences in purpose."* [12.] As part of everyday teamwork, the documents will be viewed by different people at different times but each will add to the 'repository' through annotation, and thus the repository as a whole can be used as a means of assembling a version of the current state of any particular road scheme.
Both the report templates and the surveyor's plans which were used for calculation and annotation were important in terms of their 'procedural implicativeness'. This encompasses their role in informing and guiding the actions of others - an activity assisted by its 'at-a-glance-visibility' of what work had been accomplished, what calculations done, what measurements taken and so on and their 'at-handedness' as an instrument of work. In this way, through the annotations, the markings and the conversations around them - and perhaps especially as evidenced by the observed practice of holding graphical transformations and representations up to the eye - these customs and practices of document re-use contribute to what Goodwin [3] terms 'professional vision'. Goodwin notes that: *"Discursive practices are used by members of a profession to shape events in the domains subject to their professional scrutiny. The shaping process creates the objects of knowledge that become the insignia of a profession's craft: the theories, artifacts, and bodies of expertise that distinguish it from*

other professions. Analysis of the methods used by members of a community to build and contest the events that structure their lifeworld contributes to the development of a practice-based theory of knowledge and action." The engineers' discursive practices of annotation and talk around documents constitutes these documents as part of their craft. A well drafted plan is evidence of the civil engineer's professional skill, but it becomes an engineer's object in and through the discursive practices that take place *inter alia* in reading, annotating and discussing the plan, this is where professional vision lies. As Goodwin notes, it is through coding, highlighting and 'producing and articulating material representations' that "*participants build and contest professional vision, which consists of socially organised ways of seeing and understanding events that are answerable to the distinctive interests of a particular social group."*

As already noted, a grossly observable feature of document work in road safety audit, and a natural outcome of the working division of labour, is the phenomenon of sharing documents. Taking documents across to other people, placing it on their desk and orienting them to particular documents within a collection or particular parts of documents such as annotations or calculations by pointing at them was a regular feature of everyday work. The fact that paper documents can be and are used in this way is significant. A good measure of the meaning and the significance of shared objects - such as documents - within the world we inhabit is tightly bound up with the interactional methods through which those objects are shared. Objects do not self-evidently have a precise motivational force. The motivational force of many objects is bound up with the manner in which those objects are delivered or presented to us. What we come to understand about an object is not merely contained within the object itself but is connected to the way in which that object was presented. Objects are prefaced in interaction and prefacing is more than verbal introduction but involves pointing, showing, highlighting and so on. It is implicitly bound up with the way objects are shared in a mutually constituted interactional space. When an object is motivated in someone's direction it is presumed by the recipient to have some intentionality behind its motivation. This presumption is oriented to by all of the parties to that interaction. Thus, the significance of any particular document, such as a plan, for example, or a photo, has to be projected by one party and recognised by the other and necessarily has to be achieved within the manner of the passing over, bringing to attention, putting forward and so on of the document itself.

Documents used within these domains are observably used to provide or afford 'at a glance visibility', enabling the engineers to discern and appreciate what work is going on with the document and what work remains to be done. The documents are presented and used so that, for example, the engineer and his supervisor can examine them together. In this fashion, as the fieldwork shows, the document effectively becomes enmeshed in the various practical ways whereby the road safety audit team collectively accomplish particular aspects of work, enabling them to point to particular sections, mark interesting or relevant parts of the document and so on. The marking and annotation of documents, the appearance on the document itself of shaded in areas, calculations, and annotations, are a physical reminder of how the job is progressing and what remains to be done. They represent a physical representation of issues and problems to be addressed and things to bear in mind – like the width of pavements and cycle ways, for example. The documents thus possess an 'ecological flexibility' that facilitates the interleaving of practical discussion with physical mark-up of the document, mark-ups that are, in turn, used to complete the work at hand or initiate new work. Such co-working is not restricted to annotation and marking but includes various kinds of physical activity. This includes, for example, instances where a document (a graphical representation of the transformation of chainages from the survey plan) was held up to the eye to see the slope and the transition, where the 'flat point' was – whether it had moved sufficiently. In a similar fashion the physical layout of the desk was deployed to maximise utility and visibility and the facility for cross-referencing. Documents, such as plans, were laid out so as to facilitate, for example, the physical marking and concentration on a particular area of road or bridge, while simultaneously searching for different views such as vertical cross-sections or photos or other relevant information such as the positions of gas mains, or the results of road samples etc. Finally, it might be suggested that another physical characteristic of the documents used by safety engineers was their easy mobility which meant that the plans, for example, were physically suited to aspects of everyday working life and, in particular, the various site visits.

The various social features of documents, noted elsewhere, were also readily apparent in document use in road safety audit. That documents are integral to socially organised patterns of work was clearly observable - in the case of safety audit and assessment this applies whether we are concerned with individual work or teamwork. Given the complexities of road safety audit, the involvement of various statutory and regulatory agencies and services, documents are essential to managing complexity in various ways. Documents - in the form of plans in particular - are the focus for various kinds of work, are shared, and have a procedural implicativeness for the work. The templates used in road safety reports are both a representation of organisational actions - that is, they are indicative of progress on a particular scheme - but they are also sedimentations of the organisation's activities. Documents are organisational objects and consequently represent and reveal organisational work. They are indicative, in the presence of particular attachments or other documents - maps, plans, photos and so on - of the kind of work others have already accomplished. Documents are 'shared objects'

and for those who know how to use them can constitute a means of making the activities of the organisation accountable and available in various ways. The use of documents and the informal interactions that surround that use can be seen as integral elements in the generation of the orderliness of activities, maintaining co-operation and collaboration.

As we progress toward a better understanding of knowledge work and document re-use, it is clear that the opportunities for technical support are likely to vary according to whether the activities in question are open-ended or structural, co-proximate or physically separated. It would appear, for example, in structured knowledge work of the kind undertaken by civil engineers undertaking a road safety audit, that the form or format of the information is of great importance. Modal transformation of this form - through the 'bubble diagrams' for example - enables knowledge workers to interpret the information in more insightful ways. Accordingly, applications that allow the transformation of the same content and the presenting of it in new forms may prove useful. This may be complicated, however, by the fact, observed in this study of civil engineers, that sometimes knowledge workers find that attending to the process of the modal transformation can itself be of some value in their work, enabling them to 'get a picture' of the phenomena. It can also be complicated by the fact that knowledge workers often want to transform content from digital to non-digital media and back again. This creates particular problems exacerbated by the fact that such work often involves complex arrays of digital and non-digital forms.

The problem of co-proximity in knowledge work has its own set of implications for digital re-mastering tools. Amongst the features of co-proximate work is the fact that any particular item of information is part of locally organized ecologies of informational artefacts. This ecology will provide a resource through which the meaning and purpose to any item may be elaborated. The same ecology will be important when trying to re-purpose that item of information for new uses and digital re-mastering tools are unlikely to be able to replicate the full richness of these ecologies. If these tools are provided within the same ecology, it may be possible that the ecology itself will enable those tools to be effective. If the tools provide the re-mastering opportunities in remote ways, however, the relationship with the local ecology will be rendered useless. This is not to say that re-mastering tools cannot help support distance work, but it is to say that such tools cannot be understood as freestanding items. They necessarily need to be thought of as part of an amalgam of tools that knowledge workers utilize, only some of which are subject to digital processing. This returns us to the point about design and deployment made by Berg [1] which although about an entirely different domain remains cogent nevertheless, of the need to understand both work practice and tools and their interrelation in and through use, their 'co-evolution':

"… *searching for ways in which such tools may become familiar yet never totally transparent, powerful yet fragile instruments of change."*

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