The East Lancashire Institute of Higher Education at Blackburn College

East Lancashire Research

2007

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Edited by Stephen Kirkup[1], Trevor Green, Barry Powell and Stephen Pickles

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Preface

This document came about as a result of the coordination of research activity by the recently-established Research Committee within East Lancashire Institute of Higher Education (ELIHE). The document and the associated web site (ww.east-lancashire-research.org.uk) is produced to disseminate research output within ELIHE and Blackburn College in particular and to East Lancashire and more widely.

Brian Whitehead[1] (Dean of Higher Education) and ELIHE management initiated the Research Committee of the East Lancashire Institute of Higher Education (ELIHE) in December 2005. The Research Committee has four members, one appointed from each of the four main *Schools;* Trevor Green[2] of the *East Lancashire Business School*, Stephen Kirkup[3] of the *School of Science and Technology*, Stephen Pickles[4] of the *School of Integrated Arts* and Barry Powell[5] of the *School of Social Sciences and Humanities*. The *Research Committee* aims to support, promote and widen participation in research-related activities by ELIHE staff in particular and in East Lancashire in general.

The *Research Committee* has recognised. three *Research Groups* within ELIHE: 1. *Criminology,* 2. *Engineering* and 3. *Sustainable Development*. Other ELIHE research themes include *Art and Design*, *Cluster Computing, Education, Intelligent Control, Literature, Organisational Development, Social Theory,* and *Knowledge/Information Management/Systems.*

Perhaps the question that most people would ask is *why should an institution like ELIHE be involved in research?* There are a number of answers to this question. One reason is that research activity is the natural method of professional development for a number of staff at ELIHE. A second reason is that research activity provides a context in which curriculum or course development can take place in higher education; research provides a link between a course and the outside world. A third reason is that it research often creates and maintains links between the ELIHE and partners in other institutions such as other education institutions, companies and public services. A fourth reason is that research activity provides a focus for student project work and provides themes that can be used in delivering modules. Please forgive the *educationalese* but research activity enhances the *quality* the student experience, and hence improves *retention*, *achievement* and *recruitment*!

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I would like to thank my colleagues on the Research Committee, Barry, Trevor and Stephen for the ease with which we have been able to define what we are about and make decisions. I am grateful to those who have contributed to the sum of our research at ELIHE, particularly those who have been involved in penning our Academic Report series. I would like to thank Tony Dorey of Lancaster University for his advice in developing the Academic Report series. Finally I would like to thank Brian Whitehead and the HE management team for their enthusiasm in establishing the Research Committee and in endeavouring to make research a strong theme within the overall ELIHE activities.

Dr Stephen Kirkup

Research Committee (chair)
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Contents

BULLETINS

East Lancashire Institute of Higher Education

The East Lancashire Institute of Higher Education (ELIHE) is part of Blackburn College. ELIHE provision is mainly delivered in its own site within the Blackburn College campus, close to Blackburn town centre and provides a convenient and secure environment for study. The Dean of ELIHE is Helen Mathers[1].

ELIHE consists of five schools:

East Lancashire Business School (contact Steve Whewell[2])
School of Education (contact Steve Wright[3])
School of Interated Arts (contact Cheryl Dunn[4])
School of Science and Technology (contact Steve Wright[3])
School of Social Science and Humanities (contact Roshani Swift[5])

East Lancashire comprises of a cluster of towns including Accrington, Bacup, Barnoldswick, Blackburn, Brierfield, Burnley, Clitheroe, Colne, Darwen, Great Harwood, Haslingden, Nelson, Oswaldtwistle, and Rawtenstall. ELIHE has over 2000 students studying a wide range of programmes, about two thirds of all of the higher education in East Lancashire is delivered by ELIHE. East Lancashire does not have a University, but ELIHE is the nearest thing to a University in East Lancashire. In 2007, work begins on a new Higher Education building, due to be completed in 2008 to accommodate the growth in the H. E. student population.

If you would like to know more about ELIHE then please visit the website. If you wish to be involved in research, teach, study or be involved in any other way with ELIHE then please get in touch with us at the most relevant contact on this page or within this document.

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Blackburn College

Blackburn College, with its base in Blackburn in East Lancashire, UK, has a long tradition of providing education, higher education and training locally and today is a vibrant place to study. With strong links in Blackburn, East Lancashire, nationally and overseas with business, partners, other colleges and schools, Blackburn College is a major force for progress in the local community and business sectors - and transforms lives and opportunities for individuals, some of whom lives many miles away.

Blackburn College's Mission

Blackburn College aims to be a centre of excellence for demand-led education, to be the provider of choice for employers and to work with learners and stakeholders to enhance employability and social cohesion across Lancashire.

History

Blackburn College was founded in 1888 as the Technical College for the town. Its initial curriculum base was vocational with a strong emphasis on Textiles and Engineering, as well as Art, Physics, Chemistry and Building. The original Blackburn College building is still in constant use today and is known as the Victoria Centre, housing amongst other things the College's Music and Media Departments. It is a Grade II listed building and has recently been extended at a cost of around £4.4 million, which included a 35% contribution from the Learning and Skills Council.

The Blackburn College's New Victoria Centre is the latest in a phased programme of re-investment, and the new building includes:

- A commercial production kitchen, serving a working restaurant open to the public, a training kitchen and a cake decoration room
- A new café bar
- Four new hair salons, beauty rooms and a spa area
- New classroom and IT facilities for the business and computing centre
- The provision of a lift enabling disabled access to the old Victoria building, which was previously inaccessible to those with mobility difficulties

In 1984 the academic / tertiary element was introduced when the local schools' sixth forms were centred on Blackburn College as an Institute of Tertiary Education offering A Levels and GCSEs.

Recent History

In 2002 Blackburn College was awarded its first Centre of Vocational Excellence (CoVE) in Digital Communication Technology and since then has gone on to achieve recognition and funding for 3 further Centres of Vocational Excellence - in Childhood Studies, Teaching Support Staff and Textiles in Fashion.

In the same year all the Higher Education offered in Blackburn College was centralised to create the Higher Education Centre, which today provides over 75% of the Higher Education in East Lancashire and is known as The East Lancashire Institute of Higher Education at Blackburn College

The Department of Education and Employment in 1998 awarded Blackburn College £750,000 to set up a Centre of Excellence for IT, in partnership with Blackburn with Darwen Borough Council, aimed at local business. This has been the catalyst for the development of very strong links with employers across all areas now in commercial training and workforce development, largely delivered in the workplace.

Further Information

Blackburn College offers a diverse range of further education courses including the areas of Art and Design, Beauty Therapy, Brickwork, Business and Legal, Carpentry and Joinery, Childcare, Construction, Engineering, Graphic Design, Hairdressing, Health and Social Care, Information Technology, Interior Design, Media, Motor Vehicle, Painting and Decorating, Performing Musicianship, Photography, Plumbing, Public Services, Science, Sport, Textiles/Fashion, Travel and Tourism. Blackburn College delivers a wide range of A and AS level courses.

ELIHE, Blackburn College's higher education centre is outlined earlier in this document.

For more information on these courses see www.blackburn.ac.uk. The prospectuses for full-time, part-time, further education, A level and higher education courses are available from the website. Hard copies of the prospectuses can be ordered.

Blackburn College, Feilden Street, Blackburn, Lancashire, UK. BB2 1LH

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Academic Reports

The East Lancashire Institute of Higher Education at Blackburn College

Academic Report: AR-07-01

Windows of Opportunity for Unpaid Work?

Phil Johnson[1] and Bill Ingram[2]

July 2007

Criminology Research Group

Also published in the *Probation Journal*, 54(1), 62-69 (2007)

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East Lancashire Research 2007, pp 5-10.

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Windows of Opportunity for Unpaid Work?

Phil Johnson[1] and Bill Ingram[2]

Academic Report AR-07-01. East Lancashire Institute of Higher Education, Blackburn, UK.

Abstract— **This article considers the implications of the Visible Unpaid Work Strategy for the unpaid work element of a community order. It argues that such a strategy is incompatible with requirement for skills development in the current delivery of unpaid work. It uses data collated from research into public perceptions of the sanction and disputes the viability of community engagement in relation to the choice of work for offenders..**

I. Introduction

Since November 2005 all probation areas have been compelled to ensure that their delivery of the unpaid work element of a community order fulfils the requirements of the Visible Unpaid Work Strategy (Home Office, 2005a). The reshaping of the sanction's role is hardly new; since its introduction in 1972, several models have been rolled out before its current classification as unpaid work. Despite a perpetual state of flux, numerically at least, it is proven as a successful sentence as five million hours of unpaid work take place every year (HM Government, 2005: 5). On this basis such judgments are likely to continue with the announcement that 'unpaid work should be at the heart of community sentences' and that by 2011 the annual number of hours should double to ten million (Home Office, 2006: paras. 3.16-17).

II. The Elements of Visible Unpaid Work (VUW)

VUW is part of the government's civil renewal policy and it is believed that community engagement is the vehicle capable of delivering this result. In essence, the strategy can be broken down into two elements: firstly to ensure that the work performed in the community by offenders is clearly highlighted; secondly to provide the community with the opportunity to directly engage in criminal justice matters by suggesting appropriate work projects for such offenders. The work is now branded as 'Community Payback' and the model for the strategy is 'Clean Up week' from March 2005 (Home Office, 2005a: Annex 1, para.3); a label providing clear evidence of what appropriate work projects are expected to entail. Indeed six months prior to VUW's national launch, predictions of the type of work that the community will propose were already being made:

"When offenders work, under supervision, on local clean-up campaigns and other improvements to a local area, residents will have a say in the type of work they carry out." (Home Office 2005b: 18)

This is a revealing statement and one that in addition to fettering community engagement also overlooks issues raised by the introduction of Enhanced Community Punishment (ECP) in October 2003. ECP was implemented following 'the largest single research project into Community Punishment (or Community Service) undertaken in Britain' (Home Office, 2003a: 18). 'The Enhanced CP model of change' holds pro-social modelling, cognitive skills modelling and guided skills learning as key interventions for impacting on the risk factors associated with offending behaviour (Home Office, 2003a: 7). Despite the latent distinctions in the conditions of generic orders, ECP still applies to sentences of unpaid work (except for low risk offenders) and seeks to provide 'a greater focus on rehabilitating offenders' (Home Office, 2003b). However, the subordination of skills development to 'the emphasis given to providing safer, cleaner, greener public places' (NOMS and YJB, 2005: 26) witnesses a return to issues raised by *Radical Alternatives to Imprisonment* in community service's initial evaluation:

"Any allocated task is likely to reflect middle class objectives and values, possibly illustrated by the present preoccupation with environmental problems. Such tasks are unlikely to commend themselves to the working class offender who is likely to see more immediate personal and social problems as having priority." (Pease et al, 1975: 62)

The preferences of working class offenders have though again been deemed irrelevant and precedence is accorded to what 'the community' is considered to demand. The

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influence of community safety is clearly apparent in VUW as both of its elements are consistent with two of the five priorities listed in the government's community safety plan for 2006 – 2009. The demand for unpaid work to visibly demonstrate that justice is being seen to be done complies with 'protecting the public and building public confidence' and increasing the proximity between the community and its public services is expected to lead to 'making communities stronger and more effective' (HM Government, 2005: 6). The Circular announcing VUW did not specify if either element should be prioritised, but only increasing visibility was worthy of being highlighted in bold type (Home Office, 2005a: Annex 1, para.13).

III. The Background to the Research

In 2000, as a result of community service's impending regeneration into the ostensibly more demanding community punishment order, a study of perceptions of the sentence was carried out by the East Lancashire Institute of Higher Education and Lancashire Probation Service. Both organisations had previously collaborated on various initiatives and research was undertaken to analyse the views of different stakeholders, namely sentencers, offenders and the public.

The views of the public were acquired via a questionnaire conducted via the structured interview method by a small group of research assistants. The initial sample target was 500 but pressures on resources and policy developments restricted that figure. The final decision to stop at 280 was taken by the Criminology Research Group at the East Lancashire Institute of Higher Education thanks to the imminent arrival of VUW and the subsequent increase in the cogency of the public's views. The interviews were carried out on visits to four town centres across Lancashire at various times and on various days of the week, including weekends. Whilst the sample was not strictly random, the type of questions asked minimised the risk of geographical bias and in addition the type of responses were similar to comparable studies therefore suggesting that the results could be generalised. The profiles of the sample were monitored throughout and according to the 2001 Census, the gender, age and ethnic backgrounds were broadly representative of the north-west of England. The closed nature of the questions and the training of the research assistants minimised other possible sources of bias.

IV. Current Public Perceptions

The data revealed that general awareness of community punishment (community service) was high as almost 94% of the sample knew what such an order entailed (see Table 1). The persistent references in the media to offenders being sentenced to a set number of hours of 'community service' (e.g. BBC News, 2005) meant that the use of the term in parenthesis continued throughout the study. The descriptions proffered by the respondents will be analysed at a later date, but the most common specific responses to the above question, were 'work in the community' and 'service to the community'. Therefore it can be said that despite changes in terminology, this particular community sentence is nonetheless highly recognisable; a view supported by earlier Canadian research (Roberts, 1988).

Table 1
Do you know what a community punishment (community service) order involves? (Please provide a brief description)

Number of responses and percentage

Yes	262	93.6%
No	18	6.4%

However, whilst the vast majority of respondents could explain what the sentence involved, only 35% knew that it was organised and supervised by the probation service (see Table 2). Therefore two-thirds of the sample could not accredit the probation service with annually overseeing five million hours of community reparation.

Table 2
Who is responsible for organising and supervising community punishment (community service) orders?

Number of responses and percentage

Probation Service	98	35.0%
Government	81	28.9%
The Courts	26	9.3%
Police	24	8.6%
Social Services	7	2.5%
Crown Prosecution Service	3	1.1%
Don't know	41	14.6

V. VISIBLE WORK

The lack of awareness regarding unpaid work's facilitator confirms a theme noted from the Carter Review, namely 'the poor visibility of community punishment' (Carter, 2003: 19). If such a view is accepted, it is of major significance as the profile of the sentence is such that it has been called 'the shop window of the probation service' (Varah, 1987: 70). VUW therefore requires areas to ensure that plaques, window stickers, posters and leaflets advertise the work that offenders have performed (Home Office, 2005a: Annex 1, paras. 13-14). The publicity campaign is to be fought on several fronts: unpaid work has been charged with acquiring 'a consistent brand and image', and consequently areas have been advised to acquire 'professional PR input' and 'to buy in PR consultancy' (Home Office, 2005a: Annex 2, paras. 4-6). Whilst this deployment of resources is clearly contentious, such policy is likely to be endorsed by supporters of "Restructuring Probation" and its vision of Probation Trusts comprising individuals with 'senior financial, business and management experience' (Home Office, 2005c: para. 15).

However, the fact that the proposed restructure received such widespread criticism may not prevent unpaid work being seen by a potential probation provider as being one of the 'specific interventions or programmes which may have minimal overheads providing them with the greatest profits for the least risk' (NAPO, 2005: para. 7.5). Such a step would conflict with both elements of VUW; public confidence will surely decrease if, as the evidence indicates, the number of breaches rises as a result of using separate providers to 'add-on' the separate parts to a community sentence (Worrall and Hoy, 2005: 210), and the fact that 49 per cent of offenders have between 2 – 5 conditions on their community order (Home Office, 2006: para. 3.15) aggravates this prospect. Additionally the disengagement of the community via the abolition of probation boards illustrates 'contestability at the expense of community and partnership' (Probation Boards' Association, 2005, para. 4.29). Furthermore, if the ideology of competition is embraced then the prospects of another ECP, a model based on 'what works' via the sharing of good practice, is extremely remote.

The required advertising may improve unpaid work's brand awareness but an obvious corollary is the potential for harm caused by the public identification of offenders. This situation is guarded against somewhat via the catchy strapline of 'badging the work, not the offender' (Home Office, 2005a: Annex 1, para. 6); a message seeking to dispel concerns that public humiliation is part of VUW's rationale. However, such fears endure as public identification of offenders will 'occasionally' be damaging and 'high visibility jackets' are to be used (Home Office, 2005a: Annex 1, para. 6 and para. 9). Nevertheless the expected reassurance from the high profile repair of the community's 'broken windows' means that this is apparently a risk worth taking (see Wilson and Kelling, 1982 for a full discussion of 'the broken windows thesis').

VI. COMMUNITY ENGAGEMENT

The second limb to VUW is community engagement and represents an extension of Garland's activation policy (2001: 124). The policy refers to the involvement of the community in fulfilling duties, such as community policing, that were previously under the sole jurisdiction of the state. According to Garland such initiatives are:

"beginning to challenge the central assumption of penal modernism, which took it for granted that crime control was a specialist task" (2001: 126).

However, the community engagement as required by VUW is less a challenge than a demolition, as the strategy endorses punishment, not just in, but *by* the community. The empowerment of the public means that the essential decision in unpaid work is now up for the public vote, and therefore probation areas have been instructed to establish various lines of communication with the community, with an email option being the most commonly repeated (Home Office, 2005a: Annex 1, paras. 20-1). Whilst resources have ruled out call centres, it is nonetheless apparent that the 'shop window' has been radically modernised via the construction of on-line engagement. The interactive nature of this relationship is augmented by the requirement for obtaining public feedback of both the choice of projects and the overall VUW strategy (Home Office, 2005a: Annex 1, para. 22). The prudence of such changes can be questioned both theoretically and practically, the latter concerns being particularly prominent when it is recognised that not all relevant staff may have desktop internet access (Home Office, 2005a: Annex 2, para. 5).

VII. Current Community Engagement Findings

In June to August 2005, Cheshire Probation Area conducted a survey of their beneficiaries of unpaid work and it is clear that even prior to the introduction of VUW, evidence revealing high levels of community satisfaction was already available (Cheshire Probation Area, 2005). The agencies providing the work were split equally between local and national and the work was deemed to have primarily benefited the local community. Additionally 80% believed that offenders' employment prospects had been enhanced as a result of the skills development in their unpaid work. The levels of communication between all relevant parties were rated highly and over 25% of the offenders continued working for the agency following the completion of their order. These findings showed that ECP's goal of motivating and educating offenders 'to see that they might have a useful contribution to make to society' (Rex, 2005: 145-6) could be realised via the current delivery of unpaid work.

However, the present study provides clear evidence that post-VUW engagement is likely to be problematic as the data reveals that a sizeable proportion of requests from the community would conflict with ECP's attention to skills development. Almost 41% of responses nominated 'heavy manual work' and 'humiliating and menial tasks' as appropriate work for offenders. The clash between VUW and ECP was noted in the Circular but apart from recognising its continuation, no resolutions were offered (Home Office, 2005a: Annex 1, para. 13).

Table 3
What type of work do you believe offenders should carry out whilst on their community punishment (community service) orders?

Number of responses and percentage

Work beneficial to the community	65	23.2%
Heavy manual work	60	21.4%
Humiliating and menial tasks	54	19.3%
Skills development	21	7.5%

The interpretations of these labels are clearly subjective but one clear finding did arise, namely the express lack of support for 'skills development'. Therefore work fulfilling ECP is unlikely to receive many nominations and yet VUW makes little reference as to how unsuccessful requests should be dealt with. Therefore a considerable administrative burden could develop for a sanction that courtesy of its USP of reparation, already attracts wide-ranging support (see Tables 3 and 4). Table 4 provides a potential solution to the conflict between VUW and ECP as 15% of the sample used rehabilitation as the rationale for their choice of work, an instructive finding considering it doubled the support of 'skills development' from the preceding question. Therefore if skills development received 'professional PR input' then public support for ECP could increase, however, given the push towards 'safer, cleaner, greener' unpaid work this is somewhat unlikely.

Table 4
What is the reason for your choice of type of work?

Number of responses and percentage

The community should benefit	106	37.9%
The offender should be punished	104	37.1%
The offender should be rehabilitated	42	15.0%

VIII. Conclusion

As a result of the plan to massively extend unpaid work, the prospect of seeing different names above 'the shop window' is evident. It is also apparent that the quality of the products on offer will clearly suffer if the 'pile it high and sell it cheap' mentality of VUW materialises. The direct involvement of the public could also raise expectations to unsustainable levels and if the community's 'broken windows' are highlighted, but not repaired, consumer support for the brand of unpaid work might not remain loyal.

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Criminology and Law Degrees at ELIHE

The School of Social Sciences and Humanities at ELIHE offers a range of degrees in Criminology and Law. Other social science qualifications that are offered at ELIHE are listed on pages 81-86.

BA Criminology

The BA initially consists of a one year full-time top-up programme, for which successful completion will result in the award of a BA (Ord) validated by Lancaster Universtiy. A further twelve months of study can then lead to the award of BA (Hons). The course aims to build on the understanding and awareness gained from the HND Criminology. There is the opportunity to specialise in a range of different subjects, particularly in the second year. On both years of the programme students are expected to participate in research projects in negotiated areas.

In the Ordinary year you will undertake introductory modules which allow you to engage in issues such as the theoretical explanations of crime, from both psychological and sociological standpoints. In the Honours year you can choose criminal justice and criminology modules to allow you to further develop your knowledge and understanding. The modules are far-reaching and include areas such as Youth in Trouble; Crime, Victims and Communities; Prisons, and Probation and Crime and the Media. The programme prides itself on giving excellent opportunities to develop research in criminology and criminal justice fields.

BA Criminology and Forensic Evidence

This degree is available on a full-time or part-time basis and is taught entirely at ELIHE. The degree is designed to help students form knowledge of how criminology provides an explanation of crime and how forensic evidence supports its investigation. It will help students to develop powers of analysis and problem solving, critical thinking, and interpersonal skills within the criminal justice field.

LLM Masters in Law

The LLM is taught in Blackburn and is franchised by the University of Glamorgan. It provides an opportunity to build on first degree studies, thereby enhancing existing knowledge, and widening available career options. The course is particularly suited to students wishing to develop their interests and skills in the field of international commercial law and practice.

LLB (Hons) Law

The LLB is a full-time 3 year course taught at ELIHE and franchised by the University of Glamorgan. The course incorporates the Law Society and Bar Council qualifying modules, essential for those wishing to practice in the legal profession, and balances the academic study of legal principles with an understanding of the essential practical skills such as
debating, mooting and presentations.

Other HE Courses in Criminology and Law

For those not ready or able to go straight on to a degree programme ELIHE has the following courses: Foundation Degree in Criminology and Criminal Justice, Foundation Degree in Financial Services and Law, HNC/D Criminology and HNC/D Legal Studies.

Further Education Courses

Related further education courses include A level Citizenship and A level Law.

For further information see the relevant web site; www.elihe.ac.uk or www.blackburn.ac.uk or telephone (Student Hotline: 01254 292929
Employer Hotline: 01254 292500)

The East Lancashire Institute of Higher Education at Blackburn College

Academic Report: AR-07-02

DC Capacitor Simulation by the Boundary Element Method

Stephen Kirkup[1]

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Engineering Research Group

To appear in the *Communications in Numerical Methods in Engineering* and presented at the BETEQ Conference, Paris 2006.

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DC Capacitor Simulation by the Boundary Element Method

Stephen Kirkup

Academic Report AR-07-02, East Lancashire Institute of Higher Education, Blackburn, UK.

Abstract—**When the direct current (DC) metallised thin film capacitor is fully charged the electromagnetic fields can be considered to have reached a steady state in which the governing equation is Laplace's equation. It is the computational analysis of the electrostatic state that is considered in this paper.**

The capacitor is modelled as a stack made up of infinitesimally thin layers of metal on polymer. An integral equation method is developed and applied to the problem of modelling the electric field. The method is applied to a typical capacitor structure and encouraging results are obtained.

1 Introduction

A capacitor generally consists of metallic conducting layers separated by thin layers of dielectric material. The metallic layers are charged by a voltage source; a potential difference is maintained between one half of the metallic layers and the other half. Electrical energy of the charged system is stored in the polarised insulating medium. Capacitors are used in both DC and AC circuits. In this work we will be considering only the DC or electrostatic capacitor.

1.1 Segmented Metallised Film Capacitors

An important class of capacitor design is the *segmeted metallised film capacitor*. Metallised film is manufactured by the physical vapour deposition under vacuum of a very thin layer of metal onto one side of a role of polymer film. To construct the capacitor, two sheets of the metallised film are wound onto a hard insulating core. The roll of metallised film will typically by 1000 layers thick. Connection to the external circuit is effected by *end-spraying* a metal such as zinc to make contact with the exposed metallic edges on each end of the capacitor roll. A number of rolls are placed in a box with the connection leads from it, this is the final capacitor product.

Air gaps may be produced within the the layers of the capacitor structure during its manufacture. Without treatment, such gaps may become the sites of discharges. By impregnating the body of the capacitor with fluid such as oil, the gaps can be filled with an insulating material, and the likelihood of a discharge occuring can be significantly reduced.

The segmentation of the film ensures that the capacitor is of a *self-healing* type. This means that a discharge tends to result in only localised damage to the capacitor structure. Hence a discharge within the capacitor generally results in only a minute loss of efficiency. In general it takes many such discharges, perhaps over several years, to significantly reduce a capacitor's efficiency. The period in which a capacitor performs within its acceptable range is called its *life*.

The metallisation is carried out so that the metallised areas are linked together. The link between metallised areas are called *fuse gates*. During normal charging the current flows through the fusegates and charge is stored in the metallised areas. Following a local discharge, current flows back through the fuse gates. If the current is large enough, local fuse gates will become damaged and a region of the capacitor within the damaged fusegates will no longer charge in normal use. It is this *self-healing* characteristic by which damage following a discharge is limited. References to further background information on the design and performance of metallised thin film capacitors are given [1][11][12].

This paper is one of several reports by the author on the computational modelling of metallised thin film capacitors [4-6]. In this paper we consider the solution of the steady-state electrostatic or DC problem (Laplace's Equation) using the boundary element method. The BEM has been applied to Laplace problems with some success for some time [6], [2], [3], [4] . In this a paper we apply a particular form of the boundary element method, that is one that models *thin* or shell strucures to the simulation of the DC field [7], [14].

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1.2 Capacitor

A typical example of a capacitor design that will be using to motivate this work is made from segmented metallised film. The capacitor consist of metallic and polymer layers, with the distribution of the metal being as shown in figure 1. The squares have dimension **18.4mm** (1.84×10^{-2}**m**). The gap between each square plate is **0.8mm** (8.0×10^{-4}**m**) and the fusegates are **3.6mm** (3.6×10^{-3}**m**) wide.

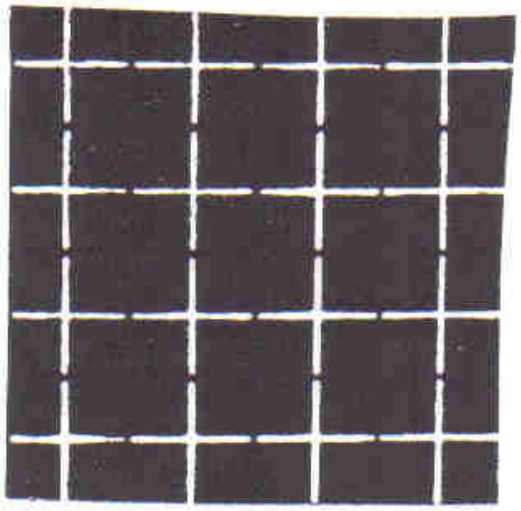

Figure 1. The metallised film.

The segmented metallised films are wound together with the aim of stacking the metallic squares one upon the other, although in practice there is some misalignment between the layers. The metallic layers are approximately **100A** (10^{-8}**m**) thick. The polymer layers are approximately **10**μ**m** (10^{-5}**m**) thick. Oil is used between the metallic and polymer layers so that the insulator is made up of two dielectrics consisting of around **90**% polymer and **10**% oil. The relative permittivities are $\epsilon_r^{polymer} = 2.2$ and - $\epsilon_r^{oil} = 2.7$.

1.3 Design and Analysis

The complex behaviour of a capacitor ensures that its optimal design is not straightforward. For example, making the dielectric layer thinner would increase the capacitance, but the propensity to discharge would also be increased, so the life of the capacitor will be reduced. On the other hand making the mosaic finer could help limit the damage following a discharge and hence extend the life of the capacitor, but the metallised area would have to be reduced so the capacitance would then be lower.

The purpose of this work is to simulate the three-dimensional steady-state DC fields that occur in a typical capacitor under normal operation. The computational model will enable us to determine the general performance of a particular capacitor design with a view to improving any given design. Examining the electrostatic fields in a capacitor, both before and after damage has occurred, could enable us to more accurately predict where damage is likely to occur in and how damage can be localised. For a recent background text on the computational solution osf electromagnetic problems see Wiak [13].

2 Modelling

The metallic plates in a typical capacitor are thin. In the capacitor the width of the plate in comparison to the intervening insulator is approximately is $100A : 10\mu m$, a ratio of **1:1000**. In the model employed in this work, the metallic plates are assumed to be of infinitesimal thickness. The model that is developed will allow a geometrically complex three-dimensional description of the thin metallic plates.

The medium of the electric field is made up of the polymer and oil dielectrics within the body of the capacitor and the external air. In the model, the insulating medium will be assumed to be homogenous. Hence for the purposes of the model the permittivity of the two dielectrics layers in capacitors like this need to be averaged. A technique for finding the volume-averaged permittivity of the medium is given in the Appendix. For the capacitor in this example ϵ_r will be approximated by **2.25**.

The structure of a capacitor, as described for example in the previous section, is very intricate. A high resolution would be needed in the model to describe the structure accurately. On the other hand, there is a high degree of uniformity in the capacitor structure, which can be exploited. In this work, only local areas of the capacitor are modelled. Where possible, the results are used to inform us of the behaviour of the whole capacitor structure.

3 Electric Field

Maxwell's equation governing the electric flux density $\mathbf{D}(\mathbf{p})$ in a region with charge density distribution $\rho(\mathbf{p})$ is

$$\nabla.\mathbf{D}(\mathbf{p}) = \rho(\mathbf{p}) \qquad (\mathbf{p} \in R^3) \ . \tag{1}$$

In regions of the domain $E(\subset R^3)$, outside the charge sources, equation (1) simplifies to

$$\nabla.\mathbf{D}(\mathbf{p}) = 0 \qquad (\mathbf{p} \in E) \ . \tag{2}$$

If the medium is linear, isotropic and non-dispersive then

$$\mathbf{D} = \epsilon\mathbf{E} \tag{3}$$

where **E** is the electric field intensity and ϵ is the permittivity of the region. Substituting (3) into (1) gives

$$\nabla.(\epsilon\mathbf{E}(\mathbf{p})) = \rho(\mathbf{p}) \qquad (\mathbf{p} \in R^3) \ . \tag{4}$$

Rearranging (4) gives

$$\nabla.\mathbf{E}(\mathbf{p}) = \frac{1}{\epsilon}\rho(\mathbf{p}) \qquad (\mathbf{p} \in R^3) \ . \tag{5}$$

The corresponding equation for the region E is as follows

$$\nabla.\mathbf{E}(\mathbf{p}) = 0 \qquad (\mathbf{p} \in E) \ . \tag{6}$$

For electrostatic problems, the electric field intensity can be written as the gradient of a scalar potential φ;

$$\mathbf{E}(\mathbf{p}) = -\nabla\varphi(\mathbf{p}) \qquad (\mathbf{p} \in R^3) \ . \tag{7}$$

Substituting the expression (7) for E in (5) and (6) gives

$$\nabla.\nabla\varphi(\mathbf{p}) = \nabla^2\varphi = \begin{cases} \frac{1}{\epsilon}\rho(\mathbf{p}) & (\mathbf{p} \in R^3) \\ 0 & (\mathbf{p} \in E) \end{cases} . \tag{8}$$

Hence in general the governing equation of the most simple electrostatic field is Poisson's equation in R^3. But outside the domain of the charge, the field is governed by Laplace's equation.

4 Potential formulation surrounding a charged thin plate

In this section an integral equation that determines the electrostatic radiation from one or more charged plates is stated. The conducting plates do not need to be flat and we will interpret the plates as being of infinitesimal width. Whilst we will be directly considering the more practical three-dimensional problem, the formulations also hold in two-dimensions, with suitable choice of Green's function.

To initiate our formulation let us start by considering the electrostatic radiation from a point source. It is well known that the potential at a point p resulting from a point source of strength ρ at q is given by

$$\varphi(\mathbf{p}) = \frac{\rho}{4\pi\epsilon r(\mathbf{p},\mathbf{q})} \qquad (\mathbf{p} \in R^3) \tag{9}$$

where $\mathbf{r} = \mathbf{q} - \mathbf{p}$ and $r(\mathbf{p},\mathbf{q}) = |\mathbf{r}|$ is the distance between the points p and q.

The function $\frac{1}{4\pi r(\mathbf{p},\mathbf{q})}$ in (9) is the Green's function for the three-dimensional Laplace equation;

$$G(\mathbf{p},\mathbf{q}) = \frac{1}{4\pi r(\mathbf{p},\mathbf{q})} \ .$$

The potential in region surrounding a plate or set of plates Π with charge distribution $\rho^+(\mathbf{q})$ on one side of the plate (Π^+) and $\rho^-(\mathbf{q})$ on the other side (Π^-) is given by

$$\varphi(\mathbf{p}) = \int_{\Pi^+} \frac{\rho^+(\mathbf{q})}{4\pi\epsilon r(\mathbf{p},\mathbf{q})} dS_q + \int_{\Pi^-} \frac{\rho^-(\mathbf{q})}{4\pi\epsilon r(\mathbf{p},\mathbf{q})} dS_q \qquad (\mathbf{p} \in R^3) \tag{10}$$

The form of the (10) can be viewed as the summation of all sources of the form (9), with contributions from charge sources on both sides of the flat plate.

The domain of the integrations in (10) are the surface charge densities on the upper and lower faces of the plate(s). (Note that the way in which the upper and lower faces are labelled is arbitrary.) Since the plate is infinitesimally thin then there is no geometric difference between Π^+ and Π^-; $\Pi^+ = \Pi^- = \Pi$. Hence equation (10) can be simplified to

$$\varphi(\mathbf{p}) = \int_{\Pi} \frac{\rho^+(\mathbf{q}) + \rho^-(\mathbf{q})}{4\pi\epsilon r(\mathbf{p},\mathbf{q})} dS_q \qquad (\mathbf{p} \in R^3) \tag{11}$$

In operator notation we may write

$$\varphi(\mathbf{p}) = \frac{1}{\epsilon}\{L(\rho^+ + \rho^-)\}(\mathbf{p}) \qquad (\mathbf{p} \in R^3) \tag{12}$$

where L is the integral operator defined as follows:

$$\{L\mu\}(\mathbf{p}) = \int_{\Pi} \frac{\mu(\mathbf{q})}{4\pi r(\mathbf{p},\mathbf{q})} dS_q = \int_{\Pi} G(\mathbf{p},\mathbf{q})\mu(\mathbf{q}) dS_q \qquad (\mathbf{p} \in R^3)$$

for any suitable function μ defined on Π

For any given set of charged plates, the formulation (11) returns the potential at any point in the external domain or on the plate(s). However, in the capacitor problem, it is the potential on the plate, rather than the charge that is given. In this case the formulation (11) alone is insufficient to solve the problem since only one function is given on the plate (i.e. φ) and two functions are sought (i.e. ρ^+ and ρ^-).

However, it is possible to augment the equation (11) with a further equation to solve the general problem, as we will see in the next section. On the other hand, in the special case that the plates are flat and coplanar, $\rho^+(\mathbf{q}) = \rho^-(\mathbf{q})$ for $\mathbf{q} \in \Pi$. In this case there is effectively only one unknown charge function on the plates in the capacitor problem and solution via equation (11) alone is possible.

5 A second equation

If we are to progress to a method of solving the general capacitor problem then a further equation, relating the functions on the plates is required. In order ro derive the equation, let us consider a point $\mathbf{p}^+$, near to the upper side of the plate, lying on the normal $\mathbf{n}_p$ at a point p on the plate. Differentiating equation (11) with respect to $\mathbf{n}_p$ gives

$$\frac{\partial\varphi(\mathbf{p}^*)}{\partial n_p} = \frac{1}{\epsilon}\int_{\Pi} \frac{\partial G(\mathbf{p}^*,\mathbf{q})}{\partial n_p}(\rho^+(\mathbf{q}) + \rho^-(\mathbf{q}))dS_q \ . \tag{13}$$

Without loss of generality, $\mathbf{n}_p$ will be taken to be a unit normal from now on.

In the limit $\mathbf{p}^* \to \mathbf{p}$ equation (13) becomes

$$\frac{\partial\varphi^+(\mathbf{p})}{\partial n_p} = \frac{1}{\epsilon}\int_{\Pi} \frac{\partial G(\mathbf{p},\mathbf{q})}{\partial n_p}(\rho^+(\mathbf{q}) + \rho^-(\mathbf{q}))dS_q - \frac{1}{2\epsilon}(\rho^+(\mathbf{q}) + \rho^-(\mathbf{q})) \tag{14}$$

where in this equation we have taken into account the well-known jump discontinuity in the operator.

It follows from Gauss's law that the normal outward component of electric flux density at the surface is equal to the surface charge density there;

$$\mathbf{D}^+(\mathbf{p}).\mathbf{n}_p = \rho^+(\mathbf{p}) \ .$$

Using the substitution (3)

$$\epsilon\mathbf{E}^+(\mathbf{p}).\mathbf{n}_p = \rho^+(\mathbf{p}) \ .$$

It follows from (7) that

$$-\nabla\varphi^+(\mathbf{p}).\mathbf{n}_p = \frac{\rho^+(\mathbf{p})}{\epsilon}$$

or

$$\frac{\partial\varphi(\mathbf{p})}{\partial n_p} = -\frac{\rho^+(\mathbf{p})}{\epsilon} \ .$$

Substituting this result into (14) gives

$$-\rho^+(\mathbf{p}) = \int_\Pi \frac{\partial G(\mathbf{p},\mathbf{q})}{\partial n_p}(\rho^+(\mathbf{q})+\rho^-(\mathbf{q}))dS_q - \frac{1}{2}(\rho^+(\mathbf{q})+\rho^-(\mathbf{q})) \tag{15}$$

Using additional operator notation and rearranging, it follows from (15) that

$$\rho^+(\mathbf{p}) - \rho^-(\mathbf{p}) = -2\{M^t(\rho^+(\mathbf{p}) + \rho^-(\mathbf{p}))\} \tag{16}$$

where M^t is the operator defined by

$$\{M^t\mu\}(\mathbf{p}) = \int_\Pi \frac{\partial G(\mathbf{p},\mathbf{q})}{\partial n_p}\mu(\mathbf{q})dS_q \qquad (\mathbf{p}\in R^3)$$

for any suitable function μ defined on Π.

Equation (15) relates the difference in the charges at either side of the plate to their sum and it provides us with the second equation that is required to solve the general capacitor problem.

The equations (11) and (16) form the foundation of our general solution strategy to the capacitor problem. First in order to simplify the appearance of the equations, let us introduce sum and difference functions for the charge distributions on the plate(s); let $\zeta(\mathbf{p}) = \rho^+(\mathbf{p}) + \rho^-(\mathbf{p})$ and $\delta(\mathbf{p}) = \rho^+(\mathbf{p}) - \rho^-(\mathbf{p})$. Hence

$$\varphi(\mathbf{p}) = \frac{1}{\epsilon}\{L\zeta\}(\mathbf{p}) \qquad (\mathbf{p}\in R^3) \ , \tag{17}$$

$$\delta(\mathbf{p}) = -2\{M^t\zeta\}(\mathbf{p}) \qquad (\mathbf{p}\in\Pi) \ . \tag{18}$$

Given the potential $\varphi(\mathbf{p})$ $(\mathbf{p}\in\Pi)$, we can use equation (17) to return $\zeta(\mathbf{p})$ on Π. Having found ζ, equation (18) can be used to find $\delta(\mathbf{p})$. It is straightforward to find the the charge distribution on either side of the plates from ζ and δ.

Having obtained ζ, the electric potential throughout the field can be obtained from equation (17) with p being the selected observation point in the domain.

The equations (18) and (18) are analagous to the standard integral equation reformulation of Laplace's equation exterior to a thin shell.

6 Solution of the integral equations by collocation

In general, the solution of integral equations such as (17) involves replacing the operator L by a matrix and the functions ζ and φ on Π by vectors. There are a number of integral equation methods that can be employed to do this. In this work the most straightforward of these methods is applied; the collocation method. Collocation can be applied in a remarkably elementary form, and is derived by approximating the surface functions by a constant on each panel.

First the plate (or plates) Π is assumed to be expressed as a set of panels; $\Pi \approx \tilde{\Pi} = \sum_{j=1}^n \Delta\tilde{\Pi}_j$. For example the open surface(s) Π can be represented by a set of planar triangles. A square plate can be exactly represented by planar triangles, as shown in figure 2. Note that the notation $\tilde{\Pi}$ is introduced since the surfaces made up of panels is an approximation to the original surface in general.

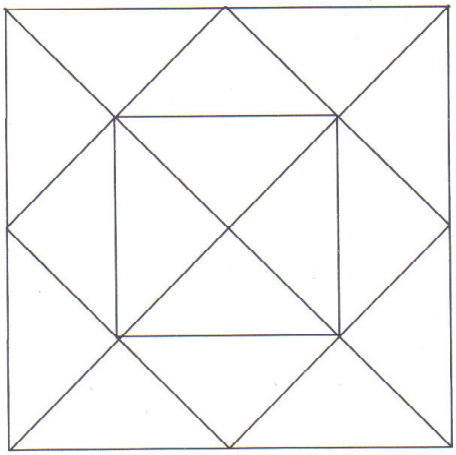

Figure 2. Triangular mesh.

The collocation method involves representing the surface function by a constant on each panel. For example

$$\varphi(\mathbf{p}) \approx \varphi_j \ , \quad v(\mathbf{p}) \approx v_j \quad \text{if} \quad \mathbf{p}\in\Delta\Pi_j \ . \tag{19}$$

The substitution of representations of this form for the surface functions in the integral equation reduce it to discrete form. The combination of the representation of the panels and the approximation of the surface functions, as typified by (19), defines the element.

The simplifications allow us to re-write equation (17) as the approximation

$$\varphi(\mathbf{p}) \approx \frac{1}{\epsilon}\sum_{j=1}^n \{Le\}_{\Delta\Pi_j}(\mathbf{p})\ v_j \qquad (\mathbf{p}\in S)$$

where e is the unit function ($e\equiv 1$). The $\{Le\}_{\Delta S_j}(\mathbf{p})$, for example, for a specific point p, are the numerical

values of definite integrals and are termed the discrete form of the L integral operator.

The constant approximation is taken to be the value of the surface functions at the representative central point (the collocation point) on each panel. By finding the discrete forms of the relevant integral operators for all the collocation points a system of the form

$$\varphi_i \approx \frac{1}{\epsilon}\sum_{j=1}^{n}\{Le\}_{\Delta\Pi_j}(\mathbf{p}_i)\ \delta_j \tag{20}$$

for $i = 1, 2, ..., n$ is obtained by putting $\mathbf{p} = \mathbf{p}_i$ in the previous approximation. Note that because of the surface approximation and approximation of the surface functions, the discrete equivalent of equation (17) is an approximation relating the exact values of the surface functions at the collocation points. This system of approximations (20) can now be written in the matrix-vector form

$$\underline{\varphi} \approx \frac{1}{\epsilon}\mathbf{L}\underline{\zeta} \tag{21}$$

with

$$[\mathbf{L}]_{ij} = \frac{1}{\epsilon}\{Le\}_{\Delta S_j}(\mathbf{p}_i)\ . \tag{22}$$

The vectors $\underline{\varphi}$ and $\underline{\zeta}$ represent the exact values of φ and δ at the collocation points. The approximation between the exact values (21) can be interpreted as an exact relationship between approximate values;

$$\underline{\varphi} = \mathbf{L}\hat{\underline{\zeta}}, \tag{23}$$

where $\hat{\zeta}$ is an approximation to ζ.

The terms on the right hand sides of the equations in (22) are definite integrals that need to be computed to return their value on the left hand side of the equations. The process of computing the integral is termed the discretisation of the integral operators using the *LSEM3* subroutine from the author's *BEMLAP* Fortran library.

Once the approximation of $\hat{\underline{\zeta}}$ is obtained, the next stage is to find δ, the approximation to the charge differences at the collocation points. For this it is possible to derive the discrete equivalent of equation (18);

$$\hat{\underline{\delta}} = -2\mathbf{M}^t\hat{\underline{\zeta}}\ \ ,$$

where $\mathbf{M}^t$ is the matrix defined by

$$[\mathbf{M}]_{ij} = \frac{1}{\epsilon}\{M^t e\}_{\Delta S_j}(\mathbf{p}_i)\ .$$

Since $\hat{\underline{\zeta}}$ is known then $\hat{\underline{\delta}}$ can be obtained through matrix multiplication.

Having obtained $\hat{\underline{\delta}}$ and $\hat{\underline{\zeta}}$, the actual approximations to the charges on either side of the plates can be obtained using

$$\hat{\underline{\rho^+}} = \frac{1}{2}(\hat{\underline{\zeta}} + \hat{\underline{\delta}})$$
$$\hat{\underline{\rho^-}} = \frac{1}{2}(\hat{\underline{\zeta}} - \hat{\underline{\delta}})$$

7 Test Problems and Results

In this section the computational model will be used to simulate the *3M* capacitor. The electric field will be studied along with the charge on the plates. The effect of removing two layers of plates and the effect of end-spray will also be considered.

In the modelling of the capacitor, the straightforward approach would be model a stack of 1.84cm×1.84cm plates, with the gaps between the plates of width 10^{-5}m. However, to model such a system accurately using the method described in the preceding sections requires that the gap is the order of at least one element thick. Hence the plates would need to be divided into a large number of panels; the computational problem is too large.

Actually the plate size does not significantly effect the charge distribution and central electric field properties, so long as the plate size is an order of magnitude greater than the gap size. This was verified through computational experiment. In the application of the method the plate size was 10^{-4}m or 0.1mm, this is still 8.5 times the distance between the plates and it was found that varying the size in the computation did not significantly affect the charge density in the results; this is presumed in the results and discussions that follow.

Note that 10 to 20 plates were generally used in the numerical experiments. It was found that this is sufficient to suggest the pattern of behaviour on the whole capacitor. Each square plate was described by a set of 32 triangular panels.

7.1 The Electric Field

The electric potential alternates between one and zero volts from plate to plate. If the field along a straight line through the plates is considered to be essentially one-dimensional then the solution of Laplace's equation is simply a straight line between each pair of plates.

In figure 3 a graph of the electric potential, on a line through the centres of the plates in a 10 plate capacitor are given. In figure 4 a graph of the computed electric field strength (effectively the derivative of the electric potential) on the same line is given. Figures 3 and 4 essentially verify that the program is working, giving expected results.

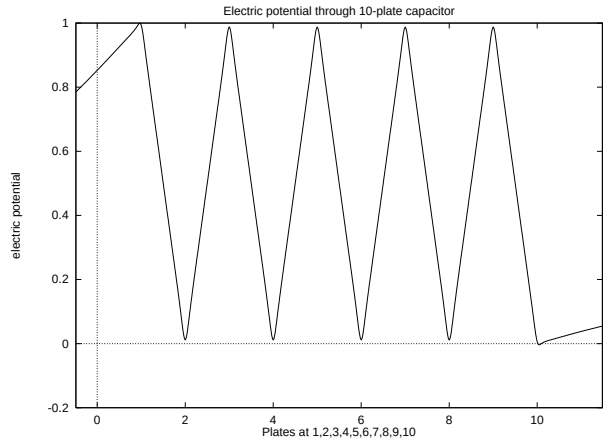

Figure 3. Electric potential on a line through the centre of the plates.

The model assumes that the plates lie in an infinite uniform dielectric material with the electric potential decaying like at least as fast as O($\frac{1}{r}$) as $r \to \infty$. Hence above the top plate and below the bottom plate the potential will eventually decrease to zero with increasing distance from the capacitor. In these simulations we are interested only in the local behaviour of the electrostatic field surrounding the plates.

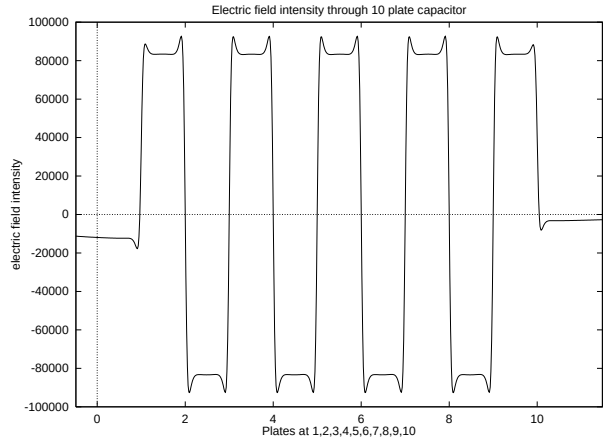

Figure 4. Electric field intensity on a line through the centre of the plates.

Note that the electric field intensity is close to uniform between the plates. The *horns* close to the plates are suspected to be due to the size of the plates in the model (i.e. 0.1mm) and would be expected to be smaller if the plates in the model were larger.

Note that the electric field intensity is not entirely symmetric; it is much higher beyond the top (1 volt) plate than it is beyond the bottom (0 volt plate). However, this can also be observed in figure 4 where the gradient of the potential above the top plate is greater then the gradient of the potential below the bottom plate.

7.2 The Charges Density on the Plates

The capacitor's purpose is to store charge; the amount of charge stored per unit volt of potential difference is equivalent to its capacitance. The computed charge density on the plates in the capacitor model is illustrated in figure 5.

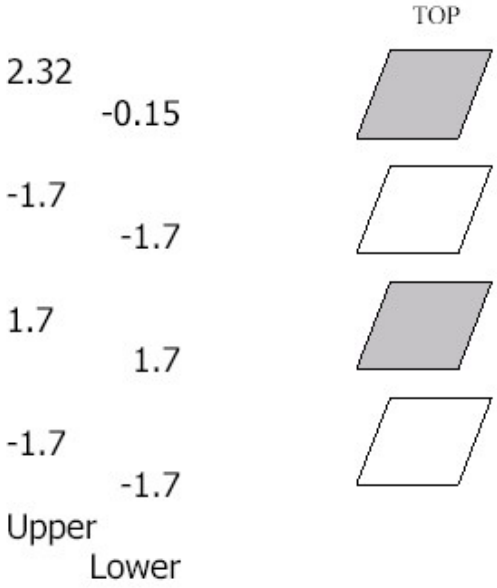

Figure 5. Charge density on upper/lower plate sides x $10^{-6} Cm^{-2}$

It can observed that the charge density on the central plates is $+1.7\mu Cm^{-2}$ on each face of the 1 volt plates and $1.7\mu Cm^{-2}$ on the 0 volt plates. Hence the charge density appears to be close toϵ/d where d is the distance between the plates. In effect each pair of plates acts as a classical two-plate capacitor. Hence if all the plates had the same charge density then the total capacitance of the capacitor is

$$C = 2\epsilon\frac{A}{d} \tag{24}$$

where A is the total area of metallisation at either 1 volt or 0 volt potential.

However, the outer plate does not follow the same pattern. The total charge is 2.1, less than the total charge of magnitude 3.4 on the central plates; the outer plate carries less charge. Moreover, the charge is different on each side of the outer plate.

7.3 Effect of Localised Damage on the Plates

During its use, a segmented metallised film capacitor suffers local damage due to discharges of current. In the following test two central plates are removed from the capacitor. The solution of the electrostatic problem in this case illustrates the change in the electrical properties after a breakdown.

Figure 6 shows the computed electric field intensity along the central line in the 10-plate capacitor with plates 5 and 6 removed. It shows that the intensity between plates 4 and 7 is about one third of the magnitude of the intensity between any other pair of plates. This seems reasonable, since the distance between plates 4 and 7 is three times the distance between any other pair of plates.

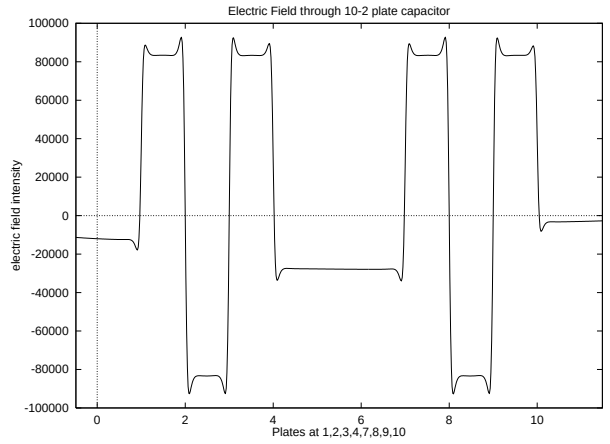

Figure 6. Electric field intensity on a line through the centre of the plates.

After the pair of plates have been damaged, they can no longer store charge in the circuit. Hence, through their removal, we would expect the loss of capacitance of the capacitor to be $a\frac{\epsilon}{d}$ where a is the area of the metallised segment. To get a better estimate of the loss of capacitance after a discharge we must observe the charge distribution on the plates surrounding the damaged area.

Figure 7 shows the computed charge on the central plates before and after two plates are removed. It can be seen that the magnitude of the charge density on plates immediately below and immediately is reduced, in fact they have a similar charge distribution to the "top" plate in figure 5. In this case the total loss of positive charge due to the damage is 4.6 rather than 3.4 (μCm^{-2}), about $1\frac{1}{3}$ times. This result was found to be similar for various capacitor designs. Hence the capacitance loss due to the loss of two central plates is approximately

$$C_{loss} = \frac{4}{3}a\frac{\epsilon}{d}$$

where a is the area of the metallised segment.

The charge that is lost on the neighbouring plates must flow as an electric current through the fusegates. The analysis suggests that one third of the plate's charge is lost. Hence the total charge that passes through the fusegates is

$$Q_{loss} = \frac{1}{3}a\frac{\epsilon}{d} \ .$$

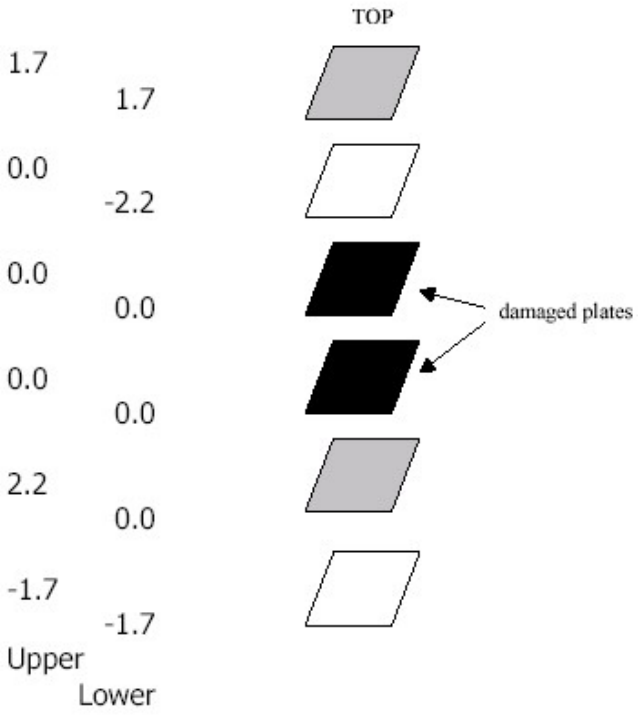

Figure 7. Charge density on upper/lower plate sides x 10^{-6} Cm^{-2} with two plates removed.

7.4 Effect of End-spray

At each side of the capacitor, the end-spray connects the plates to the circuit, with a different potential maintained at either side. Hence at the endspray there are plates at the other potential close by. In the case of the capacitor, the end-spray is around 4mm from the oppositely-charged plates.

A test was carried out to observe the effect of the end-spray on the electric properties. This was done by placing one plate to the side of 10 plates, at a distance of 1mm. The side plate was given a potential of 1V. It was found that this did not significantly effect the charge distribution on the plates.

From the computational results we can also observe that the ensprays also become charged. For this test problem the charge density was found to be 0.4 μCm^{-2} on either side. The charge was found to be invariant with changes in the distance of the end-spray from the capacitor side. Hence the total capacitance from the end-spray is 0.8μF per unit area (of 1 end-spray).

8 Conclusion

The electrostatic charge on a DC segmented metallised film capacitor consists of connected thin metallic plates surrounded by dielectric material. The metallic plates are several orders of magnitude thinner than the dielectric layers, and so present a problem if we apply the finite element or the standard boundary element method. The integral equation method applied in this paper presumes that the metallic plates have no thickness.

The method requires the triangulation of the metallic plates. The method computes the electrostatic field surrounding the plates and charge on the plates. The results for a uniform set of plates within the capacitor have been justified. Results from applying the method to non-uniform problems such as the outer plates, the effect of losing plates, the capacitance of the end-spray have been considered.

In this paper the steady state electric field within a metallised thin film capacitor has been modelled with the initial results verifying the model. The computational model has been further applied so that information about the charge distribution within a capacitor have been obtained, using relatively simple models and a limited number of elements. The way forward to more complex models would be through using higher numbers of elements and running problems on a cluster computer [5].

Acknowledgement

The author would like to thank ABB Power T&D, Ellesmere Port and the EPSRC GRM 24691 for their partial sponsorship of this work.

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Appendix: Average permittivity for a two-layered dielectric capacitor

Capacitors are often composed of two layered dielectrics between the parallel plates. If we wish to model the dielectric medium as being uniform then we need to develop a technique for finding the average permittivity of the simplified medium.

In its simplest form, the physical situation consists of two capacitor plates of area A separated by two layers of dielectrics of permittivities ϵ_1 and ϵ_2 and of depths d_1 and d_2.

This is equivalent to two capacitors of capacitances C_1 and C_2 in series the first capacitor having a dielectric of depth d_1 and permittivity ϵ_1 and the second dielectric having depth d_2 and permittivity ϵ_2. It follows that the capacitances C_1 and C_2 of the two capacitors are as follows:

$$C_1 = \frac{\epsilon_1 A}{d_1} \quad \textbf{and} \quad C_2 = \frac{\epsilon_1 A}{d_2} \ .$$

Hence the total capacitance C of the two capacitors in series is

$$C = \frac{C_1 C_2}{C_1 + C_2} = \frac{\frac{\epsilon_1 A}{d_1}\frac{\epsilon_2 A}{d_2}}{\frac{\epsilon_1 A}{d_1} + \frac{\epsilon_2 A}{d_2}}$$

Let us assume that this is equivalent to a single capacitor with of area A and thickness $d_1 + d_2$ with dielectric having permittivity ϵ. For this capacitor

$$C = \frac{\epsilon A}{d_1 + d_2} \ .$$

Equating the two expressions above for C gives

$$\frac{\epsilon A}{d_1 + d_2} = \frac{\frac{\epsilon_1 A}{d_1}\frac{\epsilon_2 A}{d_2}}{\frac{\epsilon_1 A}{d_1} + \frac{\epsilon_2 A}{d_2}} \ .$$

It follows from this that

$$\epsilon = \frac{\epsilon_1 \epsilon_2 (d_1 + d_2)}{\epsilon_1 d_2 + \epsilon_2 d_1} \ .$$

This equation is a volume-averaged estimate of the permittivity of a two-layer dielectric medium.

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The MSc programme is being prepared at East Lancashire Institute of Higher Education (ELIHE) at Blackburn College. Postgraduate qualifications in engineering and computing are planned. For the computing course, see pages 65-66.

The postgraduate programme consists of two engineering streams:

Engineering Analysis
Multimedia & Mobile Tech

These courses are for those who already hold a good Honours degree (or equivalent experience) in engineering and computing technologies or the physical sciences or mathematics area and would like to further their studies. Further information on the subject matter of each stream is given in the following pages.

There are three types of post-graduate qualification, all at the same academic level, but varying in the extent of study.
The postgraduate certificate (PGC) consists of 60 credits of technical study.
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The MSc consists of 180 credits and it is equivalent to a PGD with a dissertation.

Entry Requirements

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In modern engineering, much of the design analysis is carried out on computer. Software packages are now available that apply sophisticated techniques such as the finite element method through the meshing of the structural domain. Behind all engineering analysis techniques there lies a

computational algorithm. By understanding the background to how these methods work, engineers are better placed to develop, apply and adapt these techniques to a wide range of engineering problems and to understand the validity of solutions obtained by computer.

The topics available include Scientific Computing, Problem, Solving and Simulation by Numerical Methods, Smart Control, Systems Engineering and Finite Elements, Finite Difference and, Boundary Element Methods.

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Multimedia information exchange over wireless networks, the Internet, as well as mobile gaming and mobile commerce are nowadays the fastest growing markets in information and communication exchange. Hybrid application of wired and wireless together with ubiquitous power line infrastructure are also helping to design cost effective smart systems, intelligent home environments and, when we apply encryption/decryption techniques, they then become major tools for e-commerce, m-commerce, biomedical industries and others. Multimedia and mobile communication discipline therefore includes multimedia systems engineering, advanced networking and the internet operating systems. Availability of wireless networks has helped to realise mobile computing and indeed the development of portable devices are encouraging the engineers to apply sophisticated techniques to develop ubiquitous systems. Wireless networks are being extended to support Mobile IP and Wireless IP and GPRS. These skills are fast becoming pre-requisites for engineers securing jobs in these sectors. The course offers underpinning knowledge as to how these methods and techniques work, therefore engineers are better placed to develop, apply and adapt these techniques to a wide range of problems.

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Computing the Acoustic Field of a Radiating Cavity by the Boundary Element -Rayleigh Integral Method (BERIM) with application to a Horn Loudspeaker

Stephen Kirkup[1] and Ambrose Thompson[2]

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Computing the Acoustic Field of a Radiating Cavity by the Boundary Element - Rayleigh Integral Method (BERIM) with application to a Horn Loudspeaker

Stephen Kirkup[1] and Ambrose Thompson[2]

Abstract—**This paper describes the Fortran subroutine BERIM3 that delivers a computational solution to the acoustic field both within and outside of a cavity with one opening into the exterior domain. The mathematical model is based on coupling the usual direct boundary integral equation for the interior region to the Rayleigh integral for the mouth of the domain and the exterior region. The usual boundary element method (BEM) and Rayleigh integral method (RIM) systems of equations are coupled through the application of continuity at the mouth of the cavity. The method is applied to a horn loudspeaker.**

1 Introduction

In this report a method based on coupling the interior boundary element method (BEM) and the Rayleigh Integral Method (RIM) for simulating the acoustic field of a cavity with one opening is proposed. Such a method has a number of applications in acoustics. In this report we will be applying the method to the problem of determining the acoustic response of a typical horn loudspeaker.

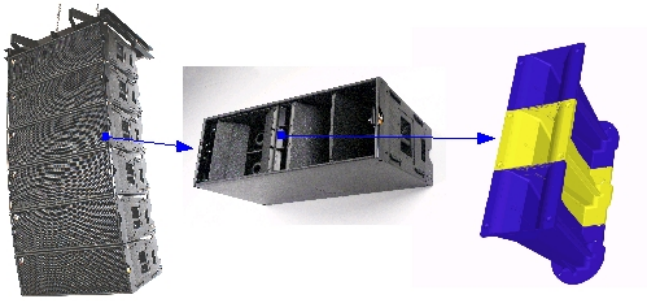

Figure 1. W8LC Line Array, box and horn element. Highlighted section modelled.

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In order to couple the BEM and RIM methods, a fictitious boundary is placed across the opening of the cavity. The interior boundary integral equation formulation of the cavity is coupled to the Rayleigh integral which governs the exterior acoustic field, by enforcing continuity in the velocity potential (sound pressure) and its derivative on the opening. The method is termed the Boundary Element Rayleigh Integral Method (BERIM) and it only requires a mesh of the interior cavity and the opening, and hence it is generally much more efficient than the straightforward application of the exterior BEM to this kind of problem.

The coupling of the integral equations gives a linear system of equations, the solution of which returns the velocity potential (sound pressure) and its normal derivative (velocity) on the cavity surface and on the opening. The acoustic properties can then be found either within the cavity using the interior boundary integral equation formulation or in the exterior region by using the Rayleigh integral. The BERIM method is developed in 3D through a simple triangulation of the cavity and the opening and the application of collocation to the integral equations to give the Fortran subroutine BERIM3. In this report the BERIM3 method is verified by applying it to the horn loudspeaker illustrated in Figure 1 and comparing the results with results from the exterior BEM.

A horn loudspeaker is a type of acoustic transducer which presents to the vibrating piston a higher acoustic resistance than experienced by a piston in free air. The shape of the horn controls the degree of loading and directional characteristics. Practical horns do not generally conform to the classical flares for example exponential or hyperbolic but are formed from geometry which

prevents simple analysis. In professional sound reinforcement horns have been an essential feature for many years, Martin Audio [27]. Amongst its virtues are higher efficiency and a control over directional characteristics. The latter has become very important in recent years, due to the advent of high power amplifiers and compression drivers built to withstand them. It is for this reason that we concentrate on the SPL and polar response in this report; results from BERIM3 applied to the horn loudspeaker of Figure 1 are presented for a wide range of sample frequencies.

2 Background

Boundary element or boundary integral equation methods have been under development over about the last five decades and in practical use over about the last three. A recent overview of the recent uses of the boundary element method is given Wrobel [35] and Aliabadi [1].

In the field of acoustics the boundary element method has also been applied in a variety of contexts. The first author's monograph [22] considers the straightforward interior, exterior and interior modal problems in 2D, 3D and axisymmetric domains. Further recent applications of the method are also published in [5], [6], [8], [13] [23], [24], [25], [28], [34].

The loudspeaker, as an instrument for creating an acoustic field, has also received much interest over the years from those wishing to model its acoustic and vibratory characteristics [2], [3], [4], [7], [10], [12], [16], [17], [20], [31].

In the method considered in this paper, a loudspeaker is considered to be a radiating cavity (the mouth), opening on to a baffle. For each individual frequency, the governing equation is the Helmholtz Equation. The solution of acoustic/Helmholtz problems with open cavities have been considered for some time [15], [29], [30].

For the loudspeaker problem there is only one opening, and this can often be simplified to that of the mouth opening on to a baffle. Now the acoustic field produced by a vibrating baffle can be recreated using the Rayleigh Integral. In this paper the Rayleigh Integral is applied to the outer radiation, however this is coupled to the radiaton from the mouth in a similar way to that used in Geddes [9].

3 Boundary Element- Rayleigh Integral Method (BERIM) Model

Boundary element methods - often more generally referred to as integral equation methods, or referred to as boundary integral methods or boundary integral equation methods - have been applied to acoustics problems for several decades. The first author's book [22] showed how interior, exterior and modal problems in two dimensions, three dimensions and in axisymmetric domains can be solved using boundary elements. The open cavity problem considered in this report cannot be directly solved by the methods in [22]. However these methods can be adapted along with other methods in order to develop a particular solution method.

There are at least three approaches to solving the open cavity problem using integral equation techniques. One method is to treat it as an exterior problem and apply the BEM by wrapping elements both around the exterior and the interior cavity walls, for example by using the AEBEM* methods [22]. A second method is to close the cavity and couple boundary integral equation reformulations of the interior and exterior regions across the openings (eg coupling the AIBEM* and AEBEM* [22]). An alternative method is to close the (one) opening of the cavity and couple the interior boundary integral equation with the Rayleigh integral (ie coupling the AIBEM* and ARIM* methods of Kirkup [19]]. It is this the third idea, boundary element- Rayleigh integral method (BERIM) that we will be developing in this report.

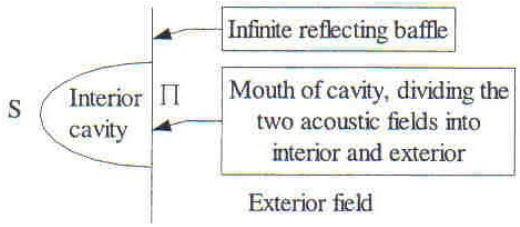


Figure 2. Preparation of model for application of BERIM.

The physical problem is now illustrated by Figure 2. The acoustic domain is the cavity and the half-space beyond the mouth. The baffle is rigid and perfectly reflecting. This model can be applied to a range of acoustic cavity problems. In any practical problem the baffle must be finite but, even

if there is no baffle, at least the continuity in the acoustic field is maintained across the mouth and the model can still be applied with due care. In the case of a horn loudspeaker, such as the one illustrated in Figure 1, there is a substantial baffle and the model is considered very appropriate. The meshes were developed using the GID software [11].

Let S be the surface of the cavity and Π the opening. The boundary condition is applied on the surface of the cavity and though for the horn loudspeaker application in this work only the Neumann condition is considered:

The boundary condition is applied on the surface of the cavity and it is presumed to be in the following form:

$$a(\mathbf{p})\varphi(\mathbf{p}) + b(\mathbf{p})v(\mathbf{p}) = f(\mathbf{p}) \qquad (\mathbf{p} \in S) \tag{1}$$

where φ represents the velocity potential and v its derivative with respect to the normal that is outward to the cavity.

4 BERIM Method

The BERIM method is derived through coupling the interior boundary integral equation formulation for points on interior cavity surface:

$$\{M_k\varphi\}_{S\bigcup\Pi}(\mathbf{p}) + \varphi(\mathbf{p}) = \{L_k v\}_{S\bigcup\Pi}(\mathbf{p}) \qquad (\mathbf{p} \in D)\ , \tag{2}$$

and the Rayleigh integral for points on Π:

$$\varphi(\mathbf{p}) = -2\{L_k v\}_{\Pi}(\mathbf{p}) \qquad (\mathbf{p} \in \Pi \cup E). \tag{3}$$

The operators in the equations above are defined as follows:

$$\{L_k\zeta\}_{\Gamma}(\mathbf{p}) \equiv \int_{\Gamma} G_k(\mathbf{p},\mathbf{q})\ \zeta(\mathbf{q})\ dS_q \quad (\mathbf{p} \in \Gamma \cup E)\ , \tag{4}$$

$$\{M_k\zeta\}_{\Gamma}(\mathbf{p}) \equiv \int_{\Gamma} \frac{\partial G_k}{\partial n_q}(\mathbf{p},\mathbf{q})\ \zeta(\mathbf{q})\ dS_q\ , \tag{5}$$

where G is the free-space Greens function for the Helmholtz equation and Γ is used here to represent any surface or part of the surface (including Π), I is the identity operator.

If we consider equation (32) for points on S and Π then we obtain the following equation:

$$\{M_k\varphi\}_{S\bigcup\Pi}(\mathbf{p}) + \frac{1}{2}\varphi(\mathbf{p}) = \{L_k v\}_{S\bigcup\Pi}(\mathbf{p}) \qquad (\mathbf{p} \in S\bigcup\Pi)\ . \tag{6}$$

Dividing the inner surface from the mouth allows us to write (4) and (6) as follows:

$$\{M_k\varphi\}_S(\mathbf{p}) + \{M_k\varphi\}_{\Pi}(\mathbf{p}) + \varphi(\mathbf{p}) =$$

$$\{\ \mathbf{L}_k v\}_S(\mathbf{p}) + \{L_k v\}_{\Pi}(\mathbf{p}) \qquad (\mathbf{p} \in D)\ , \tag{7}$$

$$\{M_k\varphi\}_S(\mathbf{p}) + \{M_k\varphi\}_{\Pi}(\mathbf{p}) + \frac{1}{2}\varphi(\mathbf{p}) = \{L_k v\}_S(\mathbf{p}) + \{L_k v\}_{\Pi}(\mathbf{p})$$

$$(\mathbf{p} \in S\bigcup\Pi)\ , \tag{8}$$

The computational method is applied by a triangulation of the interior surface of the cavity and the opening alone. By approximating φ and v by constants on each triangle and through collocation the integral equations (3),(4), and (5) can be written as linear systems of equations:

For the integral equation

(8) the following equation is obtained for $\mathbf{p} \in S$

$$([\mathbf{M}_k]_{SS} + \frac{1}{2}[\mathbf{I}]_{SS})\underline{\varphi}_S + [\mathbf{M}_k]_{S\Pi}\underline{\varphi}_{\Pi} = [\mathbf{L}_k]_{SS}\underline{v}_S + [\mathbf{L}_k]_{S\Pi}\underline{v}_{\Pi}\ , \tag{9}$$

and the following for $\mathbf{p} \in \Pi'$

$$[\mathbf{M}_k]_{\Pi S}\underline{\varphi}_S + ([\mathbf{M}_k]_{\Pi\Pi} + \frac{1}{2}[\mathbf{I}]_{\Pi\Pi})\underline{\varphi}_{\Pi} = [\mathbf{L}_k]_{S\Pi}\underline{v}_{\Pi} + [\mathbf{L}_k]_{\Pi\Pi}\underline{v}_{\Pi}\ . \tag{10}$$

respectively. The correspondence between (3-5) and (6-8) should be clear. The operators L_k, M_k and I are replaced by the matrices $[\mathbf{L}_k]$,$[\mathbf{M}_k]$ and $[\mathbf{I}]$ and the boundary functions φ and v are replaced by vectors $\underline{\varphi}$ and $\underline{v}$. For more details on this see Kirkup [22].

In the collocation method the centres of the triangles, the collocation points, are the representative points on the cavity surface and opening at which the surface functions φ and v are observed. If the cavity surface S is divided into n elements and opening Π is divided into m elements then $\underline{\varphi}_S$ is an n-vector and $\underline{\varphi}_S\Pi$ is an m-vector. With equations (6-8) we then have $n+2m$ equations with potentially $2n+2m$ unknowns. The system is completed with the n equations that are provided by the discrete form of the boundary condition (1):

$$[\mathbf{D}_a]_{SS}\underline{\varphi} + [\mathbf{D}_b]_{SS}\underline{v} = \underline{f}$$

are diagonal nxn matrices with the diagonal made up of the values of a(p), b(p) and fp at the collocation points on S.

Using equations (6-9) we can form a (2n+2m)x(2n+2m) system of equations that returns approximations to the values of φ and v at the collocation points. For purely Neumann or Dirichlet boundary conditions we can simplify (9) and in these cases we can write the coupled system as an $(n+2m)x(n+2m)$ system.

Once the surface functions are determined, results in the cavity D and the exterior E can be found using the integration.

5 Application of BERIM3 to the Horn Loudspeaker

In order to apply BERIM3 to the horn loudspeaker shown in figure 1, first the 3D solid model is generated automatically from a set of around 10 parameters. This is then introduced into the popular GID pre/post processor where a triangulation of the interior surface and mouth is made and subsequently solved. A typical GID post process mesh is shown in figure 3. A velocity of 1m/s was set at the throat (assumed to be flat) and zero everywhere else. In order to mitigate the numerical effects of the sudden change in boundary conditions where the cavity surface meets the mouth, a small flange was added. A description of each calculation can be found in Table 1, where number of elements and approximate running time on a AMD2200 PC platform are given.

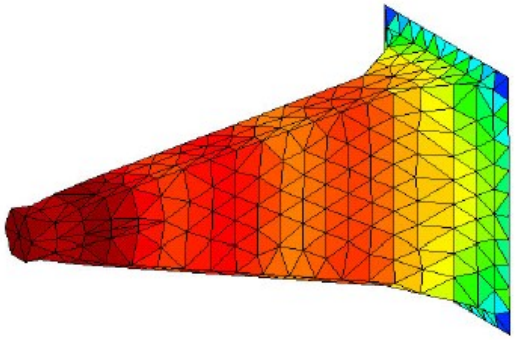


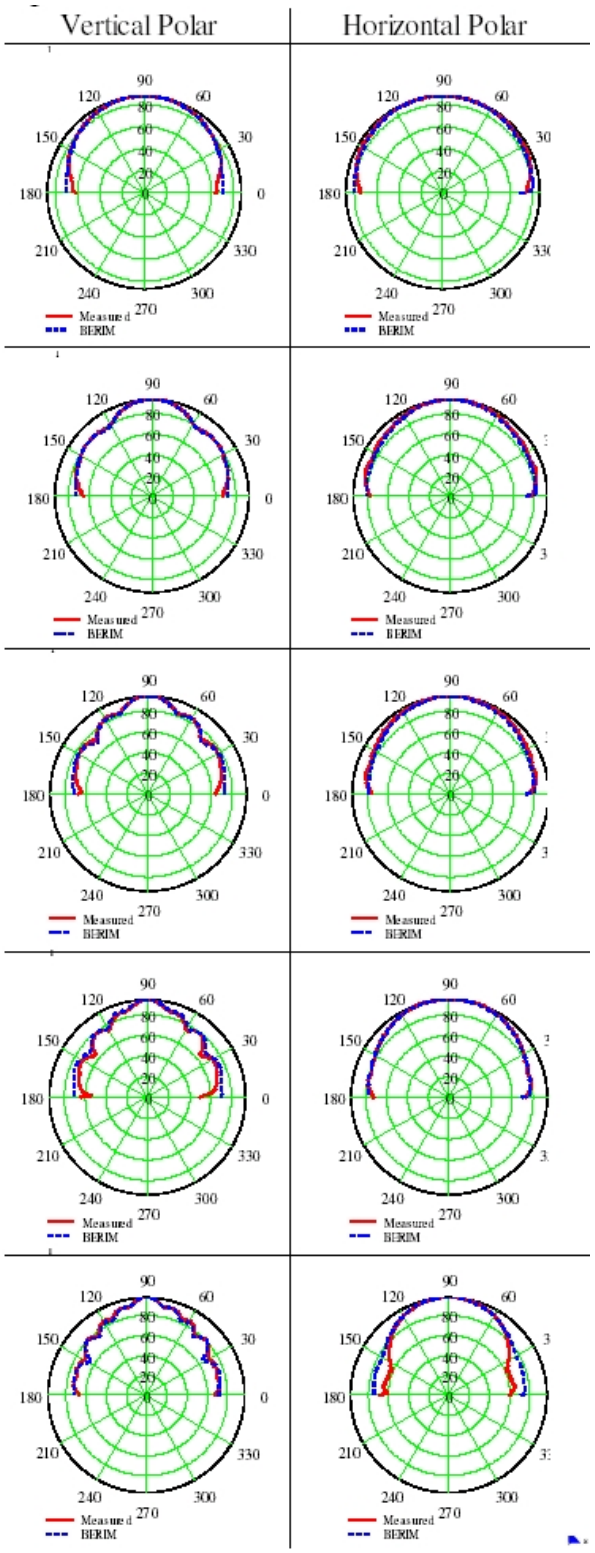
Figure 3. Typical BERIM3 mesh showing surface SPL at 3kHz.

The sound pressure is observed on polar paths of 1m radius. The results from BERIM3 are compared with measured results in Figure 4, showing polar plots of the sound pressure level (spl) in the vertical and horizontal polar plane and an illustration of the mouth velocity amplitude for 3,6,9,12,and 15kHz. The popular GID pre/post processor was used to mesh and display the results.

6 Comparison of BERIM3 with BEM

By way of comparison and further validation, the application of BERIM3 is compared with the application of the boundary element method (AEBEM3) to the same problem, but at 3kHz only. In order to apply the BEM, the mesh in Figure 5 is used. The horizontal and vertical polar plots of the SPL at 1m is shown in figure 6.

By way of comparison and further validation, the application of BERIM3 is compared with the application of the boundary element method (AEBEM3) to the same problem, but at 3kHz only. In order to apply the BEM, the mesh in Figure 4 is used. The horizontal and vertical polar plots of the SPL at 1m is shown in figure 5.



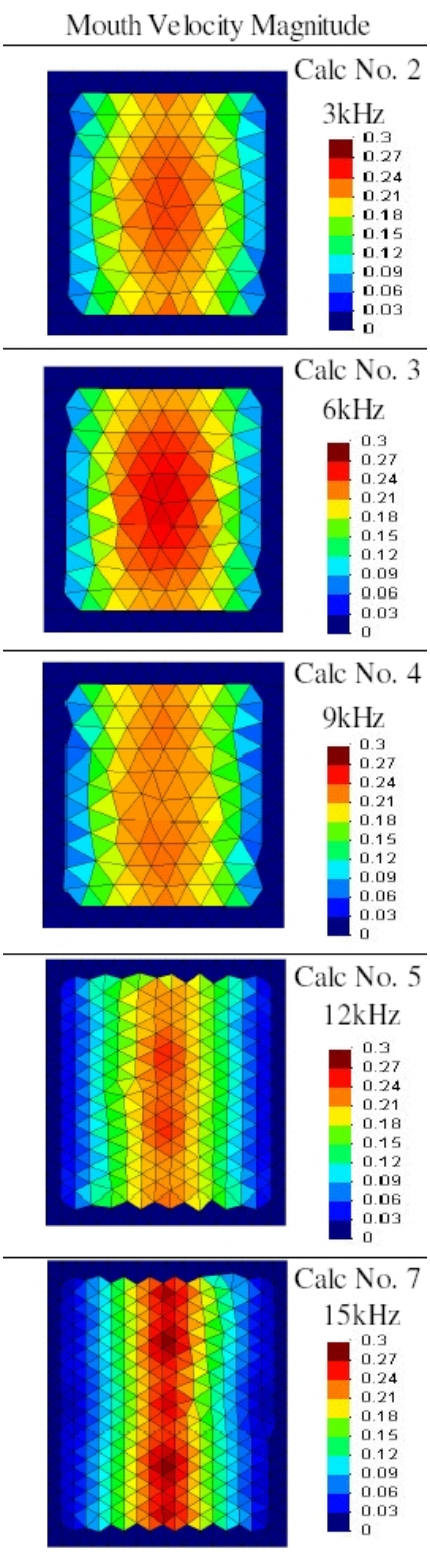


Figure 3a. Polar plots of the sound pressure level (spl) in the vertical and horizontal polar plane 3,6,9,12,and 15kHz.

Figure 3b. An illustration of the mouth velocity amplitude for 3,6,9,12,and 15kHz.

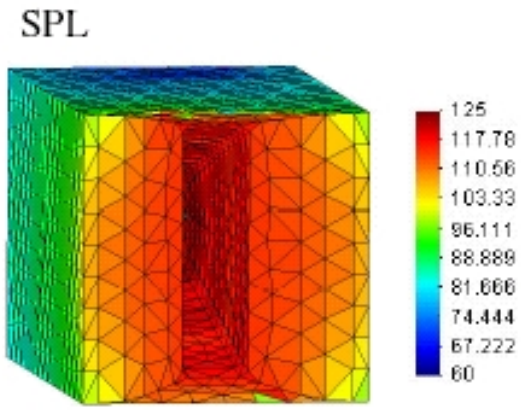


Fig 5. Mesh, showing SPL values at 3kHz.

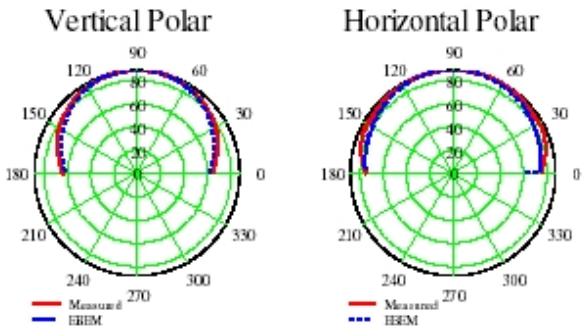


Fig 6. Horizontal and vertical polar plots at 3kHz.

7 Conclusion

For a structure such as a horn loudspeaker, which consists of a cavity (the horn) opening out on to a plane, the Boundary Element Rayleigh Integral Method (BERIM) seems most applicable. In Figure 3 it is shown that BERIM requires a mesh of the interior surface and opening plane alone whereas the application of the boundary element method (BEM) to the same problem requires considerably more elements. Hence when it can be applied BERIM3 reduces the meshing required and typically uses an order of magnitude less computer time than the straightforward BEM.

The results in Figure 6, compared with Figure 4 at 3kHz show good agreement between computed and measured results, there are a number of other points. BERIM3 seems to give better agreement with measured than the BEM in the forward field, however, near the baffle the BEM has more agreement. The proposed reason for this is that the BEM accurately meshes the baffle whereas BERIM assumes and infinite baffle; BERIM3 gives more support to the wider field than the true finite baffle.

Taking into account the comment in the previous paragraph on the modelling of the wider field, the results generally show good agreement between measured and computed in Figure 4. In generally the lobes in the sound field are captured. There is only significant drift in the horizontal polar at 15kHz: this would probably benefit from a further refinement in the mesh. The present method represents a significant improvement over our initial acoustic models [32]. In general BERIM3 is a powerful tool for the simulation of the sound field of a horn loudspeaker; returning results for a given problem and given frequency within a few minutes at low and medium frequencies on a typical modern PC.

However, more elements are generally required at high frequencies to maintain the same level of accuracy (as in low frequencies), as demonstrated by the particular example of figure 4. The greater the number of elements, the greater the solution time. Added to this, in practice a scan across the frequency range is required, typically hundreds or thousands of frequencies. Special algorithms are often necessary to speed up the solution in these cases (eg [18] or using some form of parallelisation (eg a computer cluster [14]).

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BEng at ELIHE, Blackburn

The BEng (Batchelor of Engineering) courses at East Lancashire Institute of Higher Education (ELIHE) at Blackburn College have been revised and revalidated in the Summer of 2007. The BEng is validated (and awarded) by Lancaster University. ELIHE now offers the BEng in the following streams:

BEng Mechanical Engineering

Mechanical engineers work on the design and analysis of mechanical systems such as automobiles, aircraft, heating and cooling systems and industrial machinery. The Mechanical Engineering degree combines the study of applied mechanics, heat transfer and fluid mechanics together with a strong emphasis on practical skills.

BEng Electrical/Electronic Engineering

Electrical/Electronics Engineering encompasses information technology, communications, medical electronics, computers, aerospace, robotics, automation and indeed all applications of electricity. As a specialist in this field you will be able to design, build and control electrical and electronic devices from circuits to gather and process information to large items of heavy-current machinery.

BEng Mechatronics

The word mechatronics was coined in 1969 to mean the integration of precision mechanical engineering with electronics engineering. The Mechatronics degree combines practical skills together with the essential elements of mechanical, electronic, control and intelligent systems.

BEng Sustainable Engineering

This course focuses on engineering in the context of the growing concern for the environmental, social and economic impacts. In this degree you will study the environmental management of engineering processes and the sustainable design of engineering products. Further information on this course is given on pages 53 to 54.

BEng Digital Communication Systems (Telecommunications)

The Digital Communication Systems degree combines the essential elements required for a thorough understanding of communications theory and applications. It

also includes the necessary electronics engineering content required to understand the design of the components and the design and implementation of communication systems. It provides a broad based training that integrates the core field of communication systems; it creates opportunities in modern communication and application of digital signal processing, digital multimedia, mobile systems and software engineering. Strong emphasis on practical skills is reinforced by technical literacy and understanding of communication concepts and trends.

The normal delivery of each module is usually a 3 hour or 3.5 hour lesson each week for a semester (about 4 months). Classes are normally held in the morning (9:00-12:30), afternoon (1:00-4:30) or in the evening (6:00-9:00). Most of the BEng is also available in the Vocational Educational Training (VET) Programme (see the note on that in this document).

Other Courses

Engineering postgraduate qualifications are also proposed, see pages 23-24.

HNCs and HNDs are available in the core engineering subjects of Mechanical Engineering, Electrical/Electronic Engineering and Telecommunications. See also the provision under the Vocational Educational Training (VET) Programme (see pages 93-94).

Further Education engineering courses at Blackburn College include the following:

- BTEC National Diploma in Electrical and Electronic Engineering
- BTEC National Diploma in Renewable Energy Studies
- BTEC Science
- City and Guilds Motor Vehicle Studies
- A level Mathematics, Physics
- New engineering courses in fibre optics, wind turbines, solar heating, satellite & wireless navigation, environmental engineering and broadcast technologies are planned.

For further information see the relevant web site; www.elihe.ac.uk or www.blackburn.ac.uk or telephone (Student Hotline: 01254 292929 Employer Hotline: 01254 292500)

The East Lancashire Institute of Higher Education at Blackburn College

Academic Report: AR-07-04

Quality costs in education

Trevor Green[1]

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Quality costs in education

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Academic Report AR-07-04. East Lancashire Institute of Higher Education, Blackburn, UK.

Abstract—

Purpose – The purpose of this paper is to identify the relevance of Feigenbaum's quality costs modelto managers in higher education and to put forward a possible way of implementing such a model in an educational area.

Design/methodology/approach – Following the author's Master's project into the relevance of TQM to a higher education institution, the need to increase student numbers without pro-rata increase in costs is discussed along with the subsequent need to "measure". Feigenbaum's model is described in detail with examples of industrial costs compared with higher education costs. A possible way of implementing the model is suggested with justification for the approach taken. The scope of the paper is limited to the model and its possible use.

Findings – The paper finds that taking the decision to implement the model requires a willingness to incur costs before realising savings. The examples show that planning the incurring of costs can result in the realised savings – but accurate measurement of the savings is difficult.

Research limitations/implications – The paper is a pilot study of the implementation of the model which would enable a clearer picture to emerge as to the willingness to view costs in a different way from that prevalent in the sector.

Practical implications – The paper shows that managers will need to be prepared to relinquish some control of financial resources to pay for the planned costs. Academic and non-academic staff will need to be prepared to identify failings, be prepared to identify practical ways of preventing those failings and be prepared to involve themselves in making the new procedures work.

Originality/value – The model is old, but the costs it describes are being incurred in many institutions in a haphazard way today. This paper suggests a route to making expenditure on day-to-day activities planned.

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I. Introduction

Feigenbaum's quality costs model was introduced in 1961 as a tool to assist managers in manufacturing industry. Indeed, modern concepts of quality 'it is generally acknowledged, began with Dr. Armand W. Feigenbaum…in his book Total Quality Control, first published in 1961' (Holmes 1992 p45). In the forty-four years since then, managers wanting to improve the quality of their products and services have used it in many other types of organisation. This article takes Feigenbaum's model and attempts to apply it in a practical manner to a higher educational setting. The fundamental issue that the article attempts to cover is the need for management of an organisation to be prepared to plan expenditure on certain quality aspects in order to avoid unplanned expenditure on other quality aspects.

II. The requirement to "measure"

Any modern quality system relies heavily on measurement: measurement of wastage, measurement of efficiency, measurement of performance, etc. Indeed, measurement of all aspects of an organisation assists the control of its activities. Lomas states that 'the imperative to "measure" higher education outputs is part of managerialism' (2004 pp157-165) and remarks that 'the increase in managerialism in education has been fuelled by the necessity to do more with less' (2004 pp157-165). The government, through the Quality Assurance Agency (QAA), requires that 'outcomes are carefully measured against targets established in a strategic plan to judge how well the organisation is progressing' (Williams, 2002). One of the reasons for this requirement to measure was the government's drive to increase the numbers of students in higher education without a pro-rata increase in funding. As Eriksen points out 'these changes reflect a government policy driven towards a more efficient utilisation of resources within higher education' (1995 pp14-29). It would

appear, therefore, that a system which measures cost with a view to improving the organisation would be attractive to higher education institutions whose fund providers would necessarily need to respond to this government policy.

III. QUALITY COSTS

Feigenbaum (1961) classified quality costs for 'convenience of analysis and control' (1961 p 3), failure costs, prevention costs and appraisal costs. It can be seen by the examples used to describe the costs that they were designed with manufacturing in mind – but the author has attempted to give "educational" examples for comparison.

Failure costs are those caused by failure to achieve through design, manufacture, supply and service. They can be broken down into two further categories. The first of these is internal failure cost – occurring within the organisation – including scrap, re-work and downgrading to 'seconds'. Associated with these costs are loss of production (service provision) capacity, resetting costs (to make additional items), investigation costs and correction costs (redesign and re-specification). The second is external failure cost – occurring after products (or services) are with the customer. These costs include cost of rejection at customer premises, product (or service) liability and warranty, providing replacement product (or service), loss of future orders with customer, damaged public relations and loss of credibility due to bad publicity. Deming, (1986) believes 'the unmeasurable cost of loss of future business may be much greater' than the others.

These theoretical cost categories can clearly be related to education. External failure costs would tend to dominate – if we accept (at least at this stage) that the 'customer' is the student – and could include lost classes due to staff absenteeism, repeating topics already taught due to lack of module documentation and repeating classes due to ineffectual teaching. (In manufacturing industries there are usually a number of opportunities to discover failure costs whilst they are still internal – but in education the student is visible and very close to the process so failures will tend to be immediately evident). It is also possible to give non-academic examples within education such as sending out incorrect bills for course fees, failing to inform students of examination venue alterations and failing to pass on telephone messages. Internal failure costs could include redrafting lesson plans due to inadequate specifications, re-convening examination boards due to inadequate rules and regulations along with returning typed reports for errors to be corrected.

Appraisal costs are those incurred in evaluating product (or service) quality to maintain established levels and they include inspection and test procedures. These costs can be further classified into undesirable and desirable appraisal costs. Firstly, undesirable appraisal costs include the cost of 'one hundred percent' inspection of work to sort into 'good' or 'bad' due to a previous error in the manufacturing process (or the delivery of the service) and performance checks due to a lack of confidence in procedures. These costs help reduce external failure costs but attack the symptom not the cause. Secondly, desirable appraisal costs include the cost of maintaining processes and keeping processes correct, 'first off' inspection to check process is correct and patrol inspection. This cost helps reduce internal failure costs by attacking the cause not the symptom.

In an education setting, undesirable appraisal costs include an external examiner marking all students work due to inadequate internal moderation and checking that the typist has correctly transcribed the minutes of the examination board. Desirable appraisal costs could include effective internal moderation to ensure correct marking levels, holding subject meetings in order to ensure all specialists are aware of module assessment levels within a discipline (foundation, intermediate, advanced) and regular pastoral tutor meetings to identify 'at risk' students before they 'drop-out'.

Prevention costs are those incurred whilst attempting to achieve 'right first time'. They include the cost of quality management systems, providing and maintaining the relevant equipment for manufacture (or provision of service), providing and maintaining relevant equipment/procedures for measurement, providing foolproof methods and providing adequate and constantly updated review systems. These costs help reduce appraisal costs by a process of continuous improvement.

In education, prevention costs include induction of new teachers to ensure they fully understand the levels at which they are teaching, full course and module documentation (including schemes of work, book lists, lesson plans, exercises with answers, current

and previous assignments and examinations, lists of students and current student achievement). They can further include course committee procedures, course development procedures, back-up plans to minimise disruption caused by staff absenteeism and student care procedures (to minimise 'non-academic' dropout).

Crosby maintains that any organisation can reduce its costs by expending resources on prevention and desirable appraisal costs – because these will eliminate failure costs. He says that 'I am not differentiating between manufacturing quality and service quality. All quality actions we are talking about apply, regardless of the business of the company' (1979 p 16). He goes on to say 'The most offered excuse managers have for not doing anything is that "our business is different"' (1979 p 18). Clearly, Crosby believes quality techniques can be applied anywhere – including education.

IV. Planning expenditure

The natures of these costs are such that failure costs (internal and external) and undesirable appraisal costs occur because of shortcomings in the organisation. It can be seen from their descriptions that these costs naturally occur as a consequence of a lack of control within the system. In stark contrast desirable appraisal costs and prevention costs have a nature such that they are planned by paying attention to improving the efficiency of the organisation. These costs do not naturally occur – they occur as a consequence of control within the system and work to reduce the amount of money spent on the other two. It should therefore be apparent that the latter costs will need to be paid out before any reduction is seen in the former – and there can be a substantial delay between outlay and recouping. This brings management of institutions a dilemma. Costs are permanently under scrutiny and a time lag between spending money and seeing a return – a return that is not usually readily measurable – is bound to be met with caution. After all, if we take one of those external failure costs, for example "lost classes due to staff absenteeism". If the organisation planned to provide a tutor to cover such a class, would it prevent one more student "dropping out" or would it result in one more student getting an "upper second class degree"? Probably not, at least in isolation, but a combination of planned expenditure on a number of prevention and desirable appraisal costs could result in just those sorts of occurrences.

V. Using the model

Unlike a change in strategic direction or the implementation of a new management initiative or the carrying out of a re-structuring exercise – which are often cost-reduction exercises in themselves – this sort of model can be implemented at the sharp end of the institution. In terms of successfully introducing the model it is important that the people who influence the cost generation are involved in the identification of the cost categories – they are the ones who are going to be involved in any implementation! First-line management in academic and non-academic areas of the institution can, therefore, commence a programme by involving their staff. It is not the author's intention to prescribe an approach, only to bring forward the model. However, figure 1 is an example of some of the costs that may appear in a review of an academic area. The failures highlighted in the table merely show items that are of great interest in my own institution – which have arisen by using the model described in this paper.

The number of issues to be dealt with will vary from institution to institution and between departments within an institution – and will vary over time as some are solved. It is the author's belief that the key to successful implementation of the model is the participation of the people who are involved in the activities which fall into the categories of failure costs (internal and external) and undesirable appraisal costs. It will be those people who will be able to identify real problems and they need to believe that there is a way for them to be heard.

It should also be noted that this approach is not simply a project with a beginning and an end. There will continue to be failure costs and undesirable appraisal costs even after desirable appraisal costs and prevention costs have been expended. The procedure is a cycle that identifies the need for action, takes action and reviews the effects of that action. New issues will arise. As Peters and Waterman point out there is a need to have 'a bias for action, for getting on with it' (1982).

The next stage is to plan the expenditure on the identified desirable appraisal costs and prevention costs. This leads to the trickiest part – incurring the expenditure.

VI. PREPARING THE GROUND

It is important to change the mind set. This involves moving away from accepting cost as a function of everyday operation – cost which is a function of a lack of control – to planning cost as a necessary way of gaining and maintaining control. In the implementation of this model, senior management's role is five fold:

- accepting the need for increasing expenditure in the short term
- preparing the guidelines with an initial budget estimate
- selecting a number of areas/departments for pilot "roll out"
- reviewing progress made in pilots
- being prepared to back the findings

First line management's role, meanwhile, is four fold:

- including all their staff in the establishment of the costs
- encouraging ideas
- including staff in the decision making process of what to implement
- maintaining the momentum

Finally, the staff's role is three fold:

- looking at what they actually do and critically assessing the things that do not work effectively
- finding ways to stop failure costs and undesirable appraisal costs
- making the prevention costs and desirable appraisal costs work

V IN CONCLUSION

Academic institutions have struggled to implement quality initiatives. Many have tried TQM initiatives with little success. Koch, in an attempt to clarify the animosity felt towards TQM by academic staff, points out that 'an important reason why many faculty shy away from TQM programs is that such programs are viewed as "business-like" intrusions whose presence is inappropriate on campuses' (2003 pp325-333). Elmuti et al, in their survey of institutions who had abandoned TQM, agree with this having discovered a perception that 'TQM programmes were ill suited for higher education because they required the institutions to take on a more corporate character. Individual creativity, spontaneity and variety were lessened and replaced by more standardisation and uniformity which were unacceptable' (1996 pp29-44). The initiative proposed in this article is not looking to diminish individuality. Indeed, by attempting to directly involve staff, it encourages innovative ideas for planning expenditure. It also avoids giving it a title – like TQM – which puts people off.

There is a need for early success in order to maintain the interest and commitment of all parties – so the choice of pilots is important. If people can see that planning the expenditure of some money can prevent other money from automatically draining out of the organisation due to a lack of control, then they will be more inclined to get involved themselves. I recently completed my 'masters', part of which involved interviewing college employees at all levels about their jobs. Invariably staff were frustrated by the failures they could identify within their spheres of activity – and the (undesirable) effects of "picking up the pieces".

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Failure cost	Undesirable appraisal cost	Desirable appraisal cost	Prevention cost
Students with poor attendance submitting substandard coursework for assessment	Work critically assessed. Students receiving one-to-one coaching to identify requirements to bring work up to minimum standard	Check registers for absences. Send out lesson materials to students who do not attend classes.	**Research** reasons for absence with a view to minimising problem. (We should never lose sight of the aim to attain zero absence.)
Students leave courses before completion	Questionnaire or interview, after the event, to ascertain reasons for lack of retention	Check registers for absence. Immediate contact with students on first occasion of absence to mobilise support	**Research** issues why students lose the will, commitment, etc. to follow through their chosen courses. Act on identified issues
Incorrect results letters sent out to students because of transcription errors. New letter sent out with apology and new results. (The worst effect here is the credibility of the organisation in the eyes of the student.)	Course tutor checks all letters before they are sent out	Sometimes there are no real "desirable" appraisal costs because a prevention cost can (and needs to) take care of the problem directly	**Design** information system such that lap-top computer is used directly by examination board secretary (projected onto screen for all board members). Results fed straight into results system. Letters generated from results system
Computer services department delivers inadequate service for academic needs	Log examples of inadequate service provision to use as "ammunition" against computer services department management	Measure service level. Regular contact between academic and computer services staff to "iron out" issues	**Training** staff from both sides to form a customer/supplier relationship. Staff on both sides to realise that they are both customers and suppliers to each other
Incorrect marking of student work by module lecturer	External examiner re-marking all scripts	Internal moderation identifying problems and discussing issues with module lecturer	**Training** in application of standards. Regular "standards" meetings, in each subject area, to discuss assessment issues, developments, etc.

Figure 1 – examples of types of costs relating to some typical issues

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East Lancashire Business School

East Lancashire Business School in the ELIHE delivers a range of business degrees, foundation degrees, higher nationals and professional qualifications. The HE and FE courses in business courses delivered by the ELIHE and Blackburn College are listed.

Master of Business Administration (MBA)

The MBA is an internationally recognised qualification designed for middle and senior managers to develop skills and knowledge required for further career progression. The course is up to two year's duration, and is designed to build on previously gained postgraduate knowledge and skills in the area of management and business studies.

BA Business Studies

The aim of this honours degree is to provide the student with a firm foundation in the knowledge and skills that are required in the ever-changing field of business and management. It is a three year programme that covers basic business modules and builds into an analysis of more specific areas, which will allow you to consider specialisation in a particular field of business. This degree is made up of a variety of business related modules across three levels. Students in year 1 will study Law, Accountancy, Information Technology, Quantitative Techniques, People and Organisations and Economics. Year 2 consists of Statistics, Business Operations, Business Information Systems, Organisational Behaviour, Marketing and Enterprise and Planning. Year 3 consists of Management Operations, International Business, Business Strategy, Strategic Marketing and a Dissertation. The course is designed to give students the skills required for a career in business.

BA Business Accounting

The aim of this honours degree is to provide the student with a firm foundation in the knowledge and skills that are required in the developing field of accounts. This is three year programme that builds from basic skills to incorporate specific areas that will allow you to develop in this particular field. This degree is made up of foundation, intermediate and advanced modules covering aspects of Business Studies

with a leaning towards Accounting. Students in year 1 will study six foundation units and in year 2 will study six intermediate units. On progression to year 3 students will undertake five advanced units - one of which will be an accounting related dissertation. The course is designed to give students the analytical skills required for a career in business accountancy.

Other Higher Education Business Courses

Pre-degree Business Courses include the following:

Foundation Degree in Management
Foundation Degree in Business Studies
HND Business
HND Business and Finance
HND Business and Information Technology
HND Business and Marketing
HND Business and Human Resources
HND Business and Law
HNC Business
HNC Quality Management
HNC/D in Business Operations

Further Education Courses

For those who are not ready for higher education, Blackburn College delivers the following further education business courses

BTEC Business Studies
BTEC Business and Legal Studies
A level Accounting
A level Business Studies
A level Economics

For further information see the relevant web site; www.elihe.ac.uk or www.blackburn.ac.uk or telephone (Student Hotline: 01254 292929 Employer Hotline: 01254 292500)

The East Lancashire Institute of Higher Education at Blackburn College

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The Double-Headed Coin; Sustainability & Quality in the Built Environment

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The Double-Headed Coin; Sustainability & Quality in the Built Environment

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I Introduction

It is often said that the past is another country, and this very true of business management; when the 'customer was king' and the DTI was driven by 'quality' and the work of Deming, Crosby and the other quality gurus.

Today we live in seemingly more complex world where the customer is no longer king, only a very important 'stakeholder' in a confusing mix of social, environmental and economic drivers – the triple bottom line of John Elkington.

In the past 15 years, quality management has been overshadowed by the concept of sustainable development, successfully driven to prominence by excellent people who, mostly, live outside the box of the established business paradigm.

Whilst thinking outside the box is an ideal to strive for, for those within; people outside commonly do not understand the drivers and constraints of those inside – or speak the same language.

What are needed are a few words in common and I believe these come from the 'language' of quality – let me explain.

II Loss to Society

In the other country that is the past, a Japanese engineer, Genichi Taguchi was attempting to give quality a mathematical basis and he made what I consider to be a seminal statement; saying "less than perfect quality creates a loss to society".

Herein lies the link between the languages of quality and sustainability – as any process that contains losses is by definition unsustainable, be it a machine such as a clock or an eco-system.

The existing business paradigm, which we cannot change on a time scale relevant to the present rate of environmental decay, is based on financial metrics – the costs of less than perfect quality – of not doing the right thing right, every time.

These costs can be social, environmental or economic failures within the organisation and can be continually reduced by application of the plethora of business tools developed over the last sixty years.

At its heart lies a virtuous circle of process design for sustainability, driven by the ingenuity created by a synergy of knowledge and skills, taking into account external factors.

III Building towards a sustainable future

The 2006 changes in the building regulations echo this holistic, integrated approach to looking at quality in the built environment that is driving the continual reduction in the lifecycle costs resulting from process losses at all stages of design, realisation and operation of buildings.

III. Taking responsibility for what we do.

Under this heading in the current Prius brochure it says 'Toyota's product and technology development can be summed up in two words – Zeroise and Maximise.

Toyota is striving for zero impacts on our environment and maximum satisfaction, fun and excitement. That is ***- to***

[1] School of Science and Technology, East Lancashire Institute of Higher Education, Blackburn College and Trailblazer Business Futures www.trailblazer.co.uk

maximise added value whilst minimising the loss to society.

This approach has taken Toyota to world leadership in mobility. The final step will be to sell mobility as a service rather than a product.

Concern with language may sound pedantic to many readers but the fact is that the sustainability message is not reaching out to a mass audience.

II THE DOUBLE HEADED COIN

Whilst it is increasingly being recognised that the 90+% of small businesses in the UK do not understand the language of sustainability, they do speak some dialect of the language of quality.

Quality and sustainability are the two sides of the same coin – toss it and you can only win.

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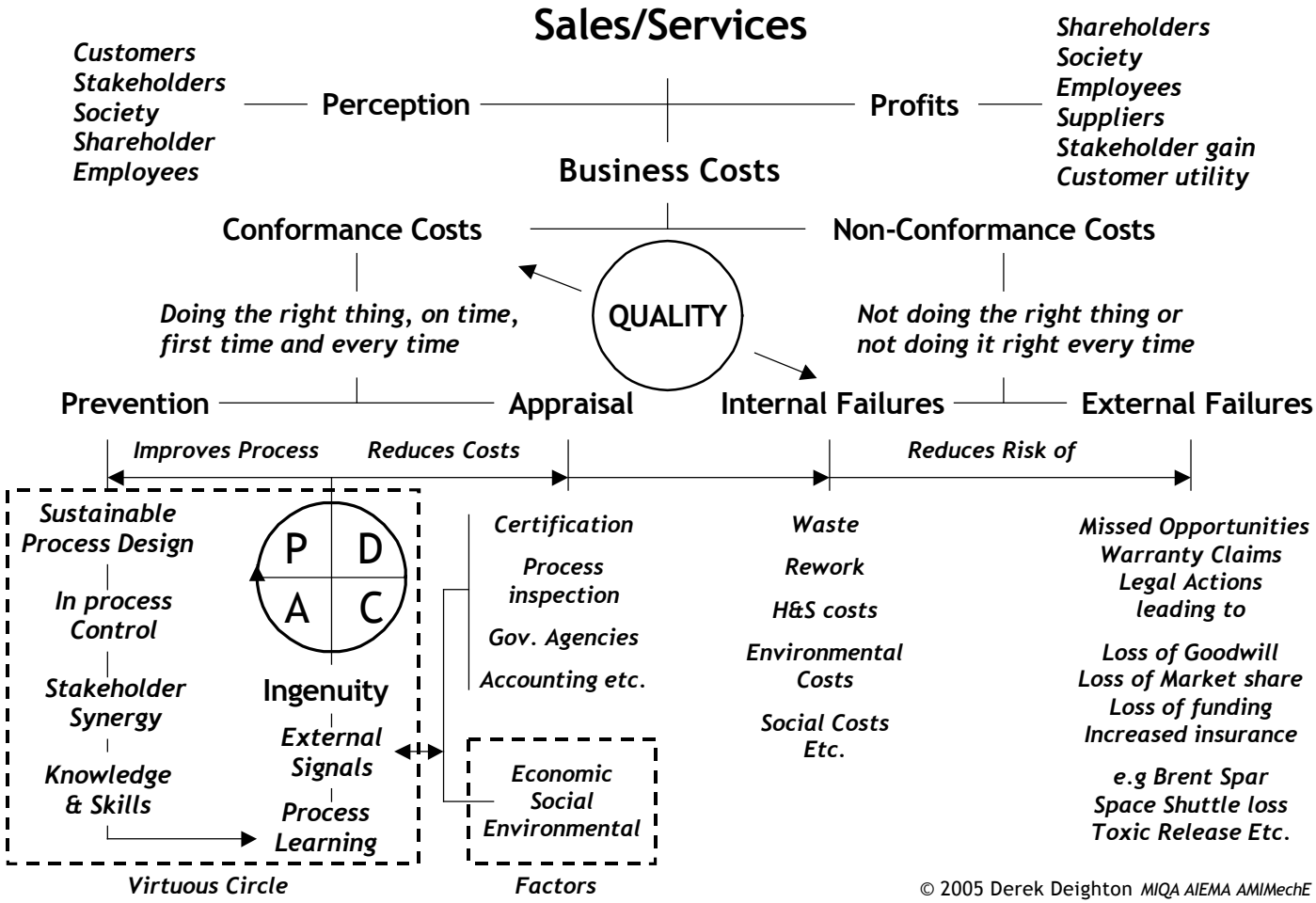
This article is also published electronically on the www.east-lancashire-research.org.uk website. Also published in the Nov 2006 edition of Environment Business and the Aug 2007 edition of Quality World.

Contact email: Derek Deighton, *derek@trailblazer.co.uk*

The Business Case for Quality

'Quality maximises the value added to society resulting from the creation, use and disposal of products and services'



BEng in Sustainable Engineering at ELIHE

The BEng (Batchelor of Engineering) courses at East Lancashire Institute of Higher Education (ELIHE) at Blackburn College have been revised and revalidated in the Summer of 2007. There is now a BEng and FDSc (Foundation Degree in Science) in Sustainable Engineering.

This course focuses on engineering in the context of the growing concern for the environmental, social and economic impacts. In this FDSc and degree you will study renewable energy and the sustainability of the choices of materials and the environmental management of engineering processes and the sustainable design of engineering products.

The wind turbine in the photo was designed and built by Adam McKenna for his final year BEng(Hons) project in 2007 at ELIHE.

The BEng can be taken part-time or full-time and can be entered at any level, subject to the qualifications, experience and aptitude of the applicant. If we think of the BEng as a three year full-time course the first year is about equivalent to a HNC/D, the second year is equivalent to a BEng(Ord) and the third year is equivalent to the BEng(Hons).

Entry to the first year usually requires 160 UCAS points, otherwise applicants are normally advised to start off on the FDSc or HNC/D qualification. For entry on to the BEng (Ord) you should have a HNC with at least an average merit or a HND with at least 6/16 merits. (Note that a Distinction counts as two merits.). For entry on to the BEng (Hons) (third year of a standard degree) you should have the equivalent of a BEng(Ord), but we would also consider an alternative entry to bridging (fast-track) to the BEng(Hons) for students with an excellent HND.

Admission to the FDSc normally requires 120 UCAS points but entry may also be based on the aptitude and experience of candidates who do not have the standard entry qualifications.

The normal delivery of each module is usually a 3 hour or 3.5 hour lesson each week for a semester (about 4 months). Classes are normally held in the morning (9:00-12:30), afternoon (1:00-4:30) or in the evening (6:00-9:00). Most of the BEng is also available in the Vocational Educational Training (VET) Programme (see pages 95-96).

HNCs and HNDs are available in the core engineering subjects of Mechanical Engineering, Electrical/Electronic Engineering and Telecommunications. See also the provision under the Vocational Educational Training (VET) Programme (see the note on that in this document).

Related Further Education Courses

Further Education engineering courses at Blackburn College include the following:

BTEC National Diploma in Electrical and Electronic Engineering
BTEC National Diploma in Renewable Energy Studies
City and Guilds Motor Vehicle Studies
BTEC Science
A level Mathematics, Physics
New engineering courses in wind turbines, solar heating and environmental engineering are planned.

For more information see the website: www.elihe.ac.uk or see the prospectus.
BEng/FDSc Course Tutor: Eric Parr e.parr@blackburn.ac.uk
BEng/FDSc Course Tutor (first year) Edd Talbot e.talbot@blackburn.ac.uk
HNC/D Programme Leader (ELIHE): James Hickie j.hickie@blackburn.ac.uk
HNC/D Programme Leader (VET): Eric Sharp e.sharp@blackburn.ac.uk
ELIHE Admissions/prospectus, telephone 01254 292594
Blackburn College Admissions/Prospectus : Tel: 01254 292929

The East Lancashire Institute of Higher Education at Blackburn College

Academic Report: AR-07-06

The ELIHE High-Performance Cluster for parallel computing

Violeta Holmes[1] and Terence McDonough[1]

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East Lancashire Research 2007, pages 53-63.

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The ELIHE High-Performance Cluster for parallel computing

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Academic Report AR-07-06, East Lancashire Institute of Higher Education, Blackburn, UK.

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Abstract

In this paper we present our experience in designing and implementing a High Performance Computing Cluster for teaching parallel computing theory and development of parallel applications. The development of the ELIHE cluster provides us with an opportunity to take a hands-on approach in teaching programming environments, tools, and libraries for development of parallel applications, parallel computation, architectures and message passing paradigms using Message Passing Interface (MPI) at both undergraduate and graduate level.

In less than a decade, clusters of shelf-ready PCs have become the most cost efficient computing platforms for computing a wide range of high performance applications from molecular biology simulations to search and indexing on the Internet. The ELIHE High Performance Cluster in our School of Science and Technology consists of 9 computational nodes and a head node. All the nodes in the cluster are commodity systems - PCs, running commodity software – Linux, and CLIC Mandrake.

We shall focus on the capabilities for messaging provided by the public domain version of MPI for computer clusters (MPICH) that is installed on the ELIHE cluster. We will consider MPI language bindings for C and FORTRAN – traditional High Performance Computing languages and JAVA programming systems. Our objective is to evaluate how these programming environments compare by considering the advantages/disadvantages of each for scientific and engineering computation and in particular for parallel computing.

1. Introduction

Over the last decade, the humble PC has taken on a new role within the industry, thanks to the recent advances in the PC's architecture and networking. The extortionate price of mainframes/super computers need no longer be paid as commodity PC's have substantially increased in processing power. According to the prediction of Moore's law 1965, transistors per square inch on integrated circuits have doubled in processing power and will continue to do so every 18 months. How true this statement has been! [1]

The emergence of clustering in computer networks has enabled a group of commodity computers to be linked and controlled to act as one processor to compete and even supersede the supercomputers of old. However, the hardware has to be connected via a high-speed LAN or switch hardware and the computers need to be of similar specifications to achieve a maximum output. It is recommended that the server be of a high specification to avoid slow down. Although the nodes are fully capable of independent usage, this is known as single system image. A single system image is achieved by the installation of a middleware layer of software to individual computers, to enable cluster operation. High Performance (HP) cluster systems provide the performance required for the applications in simulation and modelling applications while High Availability (HA) systems are often used in critical applications offering a single server with backup nodes on standby.

This improvement on the SMP (Symmetric Multi-Processing) systems allows parallel processing to take on a unique role of its own.

The diagram below shows the Cluster Computer Architecture.

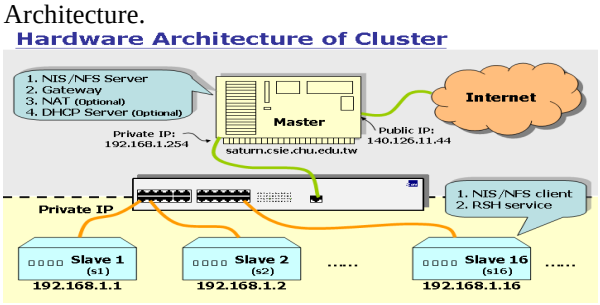

Figure 1. *From http://web.csie.chu.edu.tw/~cs87668/cluster.htm*

In the past, number crunching applications would take place on supercomputers. These days, new

advances in computer software and hardware have taken commodity PC's to new heights so rapidly that they are capable of joining as one virtual machine. Such a system could supersede any supercomputer and it allows the work to take place on idle machines during any time of the day or night, enabling the processors to compute by utilising all the networks nodes as one server farm.

In less than a decade, clusters of shelf-ready PCs have become the most cost efficient computing platforms for computing a wide range of high performance applications from molecular biology simulations to search and indexing on the Internet. In spite of countless deployed platforms and reverberating application successes, many challenges remain for achieving better performance, scalability, and usability. As the cluster architecture is becoming a more mature field of application, the areas are becoming clearer as to the new architecture and its capabilities.

2. The ELIHE High-Performance Cluster Structure

There is a need for HP and HA Cluster systems in Higher education institutions to successfully deliver courses that reflect the research on cluster technology and its practical implementation in business and scientific applications [2]. To provide a test bed for teaching Parallel Computer Architectures, Parallel Programming, Networking, Engineering Simulation and other programmes offered in ELIHE we undertook design and implementation of the School of Science and Technology ELIHE HP cluster.

The ELIHE HP cluster was set up in the Informatics Lab in the school of Science and Technology in ELIHE. This is a high performance cluster, set up and designed to work solely as an autonomous and dedicated system.

The hardware acquired was sixteen of the Institute's redundant P3 machines that are LAN boot compatible. The hardware consisted of Desktop PCs:

- 3/4Gb HD
- 128 MB RAM Minimum
- P3 440MHz CPU
- A dynamic 32-port Hub RJ11
- 10 Direct CAT 5 UTP Ethernet Cables
- 10 3/com NIC, PXE enabled 10/100
- Node Screen Resolution 1024*768
- The Master node had a 6Gb HD

The outcome of the hardware reconfiguration produced the ELIHE HP Cluster that consists of 9 computational nodes and a master node. The nodes are connected into Ethernet LAN using CAT5 UTP direct RJ45 cables and a 24 port Superstack2 dynamic hub (PS-hub50 compliant with IEEE 802.3 ISO/DIS8802/3). The NICs are PXE 3Com Fc.

All the nodes in the cluster are commodity systems - PCs, running commodity software – Linux, and CLIC Mandrake.

ELIHE HP cluster

3. Design of ELIHE HP Cluster

The overall goal of installing this system was to aid in the delivery of various courses on ELIHE programmes such as parallel computing architecture, parallel programming, engineering simulations and modelling for game design and image rendering. The system will be used by staff and students alike, adding an invaluable tool to aid in the study and teaching of these subjects.

Utilising redundant and recycled machines did encounter parts problems and resulted in machines being rendered useless due to cannibalism. To achieve 10 nodes, 16 machines had to be dismantled and re-built. However, only three initial monitors, keyboards and mice were used, as only the server node needs keyboard mouse and monitor at the implementation. The other monitors and keyboards were used for set-up and testing only. The base units were stacked on top of each other in rows of four. This created a problem with heat dissipation and required spaces between machine layers. In future, designated rack will be built to accommodate machines and prevent overheating due to the power dissipation.

Linux CLIC Mandrake (open source version 2) was the operating system chosen because it was freely available and less explored than OSCAR cluster software.

Mandrake Soft together with partners Bull and INPG/INRIA have introduced CLIC mandrake Open-ware software as a simple and easy way to create a load-balancing cluster (CLIC in Mandrake stands for Cluster Linux Calcul) [5].

3.1 Linux CLIC Mandrake Installation

The CLIC software was installed on the server and then loaded to the Nodes via a bootable disk. The LAN was enabled in BIOS to facilitate the Nodes' software installation.

We found that it is very important that the network boot option labelled LAN (Local Area Network) is activated and the 1st boot or enabled option is selected in BIOS on each machine.

The first node is assigned the status "Golden Node" and allocated Node1 address. Actually, nodes do not need a PXE-compliant NIC, although PXE-compliant NIC is highly recommended.

The server software is set up to run the following:

- Authd: Software for obtaining and verifying user credentials.
- Dhcpd: ISC DHCP (Dynamic Host Configuration Protocol) server.
- Named: A DNS (Domain Name System) server.
- Gmond and gmetad: Ganglia Monitoring Daemon.
- Nfsd: A Linux NFS server.
- Ntpd: Synchronised system time using the Network Time Protocol.
- Httpd: The most widely used Web server on the Internet (Apache).
- Pbs_server: The Portable Batch System server.
- Pbs_sched: The Portable Batch System scheduler.
- Sshd: OpenSSH Secure Shell protocol server.
- Pxe: Preboot execution Environment.
- Xinetd: To launch rsh, gexec, tftp and PCP service.

The Nodes' software is set up to run:

- xinetd: To launch rsh, gexec and pcp service.
- Gmond: Ganglia Monitoring Daemon.
- Ntpd: Synchronised system time using the Network Time Protocol.
- pbs_mom: The Portable Batch System client.
- Sshd: OpenSSH Secure Shell protocol server.

4. Building the ELIHE cluster

Incorporated in the open source software was an instruction manual, to be used for the installation process. However, during the process of CLIC installation it has emerged that a large part of the user interface functionality was missing (the commercialisation of CLIC took place during our work on ELIHE cluster). It has also materialised that a major part of the manual is incorrect and it was necessary to keep researching for answers through the web, forums and books [3,4,5,6].

The following steps contain corrections and our experience in successfully configuring the system:

4.1 Steps required to set up the server

The Graphic User Interface in CLIC Mandrake presents a user with a number of options to aid the installation and configuration of a server. They are as follows:

1. The installation asks if English set-up is required → 'yes'
2. Accept agreement licence → 'yes'
3. Cluster class – Choose cluster server not node.

There are also two options for upgrade (for the upgrade of the 1st release to this version 2). One should upgrade the package only if an important part on the installation has been missed or overlooked (such as the libraries for C and Fortran), and this option will allow an upgrade.

4. Next, the software presents a dialogue box asking if a SCSI is present; this automatically detects the availability of SCSI; in our case it displayed 'SCSI not present'. Select "enter" to continue.
5. The set up of the mouse type and the keyboard setting (UK) is automatic; no problems were found.
6. Here the software presents the installer with the security box (e-mail, password). At this stage a decision was made not to enter a password or an email address and the 'ok' button was selected.
7. Partitions must now be chosen. In this section, click on the 'clear all' on the inside box. Select cluster server, as well as the auto allocate and then 'done'. The installation then presents a number of options - select the 'ok' button to proceed.
8. Now the server choices have to be made. It is recommended by the manual that the user should install only the choices highlighted in the offered diagram. However, as a result of our experience, it is recommended that any extra options be selected to install important programming and diagnostic tools.
9. The installation presents a box that allows the installer to add further fields if now required. This is not necessary, so now click on the 'done' button.

10. Next, there is a ‘pop up’ box requesting install; press ‘yes’.
11. At this stage the installation is asking for a password to keep the root directory safe; this was chosen as - no password, because the same action can be performed after the installation of the Graphic User Interface (GUI). There is a facility to enter a password for the root files to protect the system’s integrity. Unfortunately this has proven to be a hindrance in this version of CLIC’s software, resulting in the system becoming unstable.
12. The software then finds the number of NIC’s that are to be installed. This is an option for the network to have a separate administration network. If it is selected to have one NIC then the bandwidth will be shared. On this occasion we chose to install one NIC and the installation found one NIC.

4.2 Network configuration

13. The network now has to be set up - choose the LAN setting that is highlighted by the system.
14. Now the software has found the NIC, it asks: Do you have another? Select ‘no’.
15. In this section, we decided to use the IP address 10.0.100.253 and select ‘start’ at boot ‘ok’.
16. It is recommended that you use an “end of range” (between .251 and .255) IP address for your server because by default the nodes are assigned ‘start of the range’ (starting at .1 and go up to the .250 ‘end of range’).
17. If you have two network interfaces, you must use eth0 (the first one you will configure) to communicate with the nodes (local network) and eth1 to communicate with your enterprise network to reach the “outside” world.
18. Now it is time to set up the host name, on this occasion server.enterprise.net was used. The gateway was set at 192.168.100.2, please note it is 192.168.100.1 for the DNS and the range is different to the IP.
19. In this section, I suggest that the name “cluster” in configuration software be changed to “node” and then change the range to 1 to 250.
20. From here on the manual leaves the installation up to the user, therefore in the prompt box with proxy config – select no fill as ‘ok’.
21. Next in a window with boot option “want to boot with a dual boot system press” press ‘ok’.
22. Boot loader ‘done’.
23. Making a boot disk always fails (!) so select ‘no’.

4.3 Graphic User Interface configuration

24. A ’plug and play’ dialogue box comes up with the monitor. In our case this was the right choice so ‘ok’ was selected.
25. Choose the xserver
26. Next choose x3.36, the others do not work in the GUI.
27. Choose xfree monitor resolution 800*600 .
28. Setup PC automatic ‘yes’.
29. Remove boot media notice comes up ‘remove’.
30. The system will reboot now and a password window section will appear.
31. Type ‘root [enter] [enter].
32. The initial loading is complete.

There were several errors in the installation procedure and it must be noted that the manual for CLIC Mandrake version 2 is not completely accurate or explanatory and the software installation is full of snags. There was a great deal of investigation needed to overcome the problems encountered. The system was loaded and re-loaded overcoming many problems, which were not explained in the manual. Our experiments and investigations have led us to believe that the instructions specified in this paper are accurate and the procedure outlined in points 1-32 should be followed for correct installation. Please note the server needs a hard drive with a minimum capacity of 6GB.

4.4 Post-server installation

The next section will explain the major problems that were overcome over many trials during the cluster system installation. Since part of the GUI software was missing/disabled, command line was needed to install further codes shown below:

```
setup_install_cluster.pl doall
setup_server_cluster.pl  gennodeone
setup_server_cluster.pl doall
setup_admin.pl doall
setup_compute.pl doall
setup_dns.pl master
setup_nis.pl set_server
setup_dhcpdconf_server.pl doall
setup_pxe_server.pl build
setup_pxe_server.pl setup linux
setup_pbs.pl doall
```

setup_pbs_client server_hostname.yourdomain
setup_postfix.pl set

4.5 The Golden Node installation

The golden node loaded by LAN is as follows:

To install the nodes software, the Golden node boot floppy needs to be created by typing the following instruction on the server's terminal window command line (as specified in the manual):

dd/if=/var/lib/tftpboot/PXEClient/images/cluster.im g \of=/dev/fd0 at the root directory level on the server. If you do not see that 2880 records have been written to the diskette, use another one and retry.

Insert the floppy into the golden node or the first node and switch on the machine, this will set up an auto search for the KA loader sorting out the PXE MAC address and IP addresses etc.

The configuration steps in the manual on page 19 should not be followed; there is a mistake with the main configuration script. Do not type setup_auto_server.pl. Instead type the following: setup_auto_cluster and [enter]. Automatic Exec process follows:

- xconfig
- setup_install_cluster (CD content is copied to /var/install/cluster) [enter].
- setup_NIS [enter].
- setup_dhcpconf_server [enter].
- setup_pxe_server [enter].
- setup_pbs [enter].
- setup_admin [enter].
- setup_compute [enter].
- setup_maui (with password guess) [enter].
- setup_postfix [enter].

At the end, the message will read: "Server Ready, now install a client: Install a golden node and replicate it with Ka tool. When all nodes ready and if there are 2 NIC's type: setup_add_nodes_to_dhcp.pl –c [enter]."

Follow this instruction and then launch setup_compute.pl doall [enter] and setup_admin.pl doall [enter] from the command line in the terminal window to setup the computing and administrative networks.

A fully installed system, according to the CLIC manual, is now ready to run MPI programs.

4.5 Fine-tuning the system on the Server

We were using a command line interface instead of GUI as evident from above.

From the root/etc/ directory edit the files:

nodes_list. and **nodes_list.admin** (vim opens a file for editing). Make sure the all nodes are listed in the files if not, add them to the list. In the file **nodes_list** we have entered 9 nodes e.g.:

node1.enterprise.net:1:A:patition1:0:0
node240.enterprise.net:1:A:patition1:0:0

etc, for all the nodes in the system.

Similarly in the file nodes_list.admin:

node1.enterprise.net:1:A:cluster
node240. enterprise.net:1:A:cluster, etc

We found that the following is very important - the rsh option needs editing in the file in root/etc/hosts.equiv file.

All computer nodes and the host names should be in this file; if not add them, e.g.:

node1.enterprise.net
node240.enterprise.net, etc.

In the root/etc/xinetd.d/rsh and root/etc/xinetd.d/rlogin change the disable= yes to disable= no. Then go to file /etc/pamd/rlogin and ensure that 'auth sufficient pam_rhosts_auth.so' is at the top not in the middle. Then type (on the command line in root directory) *setup_compute.pl doall* [enter] and *setup_admin.pl doall* [enter] to setup the computing and administrative networks.

4.6 Cluster administration

4.6.1 Adding a user

It is imperative here that the only codes to create a user are the special codes for CLIC software, not standard Linux.

A command line needs to be used either to add or delete users from the cluster. Mandrake clustering provides two commands to achieve that: *adduserNis.pl* and *deluserNis.pl* are simple scripts to add or remove a user in a NIS domain. When adding a user, the environment is completely set so the user can launch jobs and work on all nodes. When attempting to remove a user, a test is performed to determine if the user's home directory is mounted on a node and if it is, the procedure to remove the user is cancelled. Simply run the *adduserNis.pl* command (at root directory level) to add a new user and follow the instructions. To remove a user, run *deluserNis.pl*.

This command will now take you through a set up of the user for a group and a password. Select login and password. In our case the group was left empty and the password was entered twice as Terence. The system will automatically set up a user in a default group and is evident when logging in, the root file is replaced with [terence@cluster terence]$

Now the system was set up and ready to test.

CLIC's Cluster Software and Middleware have provided us with the following:

- Single-System Image Services.
- Software Environments and Tools.
- Standard Software for Clusters (for Application Building).

Within CLIC's cluster storage, there is a cluster I/O subsystem with I/O libraries including a real-time I/O function with a distributed file systems.

5. Parallel Programming on ELIHE cluster

Approaches to parallel programming have to be carefully considered [8]. For implicit parallelism one should consider:

- The programmer.
- Source code written in sequential languages like FORTRAN, C, C++.
- It has to have a paralysing compiler like MPICC.
- Parallel Object Code.
- Execution by run time system.

For Explicit parallelism, the considerations have to be:

- The programmer.
- Source code written in sequential languages like FORTRAN, C, C++.
- Concurrency Preserving Compiler.
- Concurrent Object Code.
- Execution by runtime.

A parallel program has to be written with the following in mind:

- Decomposition of computation in tasks.
- Assignment of tasks to processes.
- Orchestration of data access, communication, and synchronisation.
- Mapping processes to processors.

The cluster software is a middleware program that allows the computers to work on the TCP/IP protocol suit.

PBS or the Portable Batch System that has worked on the UNIX mainframes has been used to carry out the same task in this system to control the job that is submitted to a queue. The Job (a shell) can contain the script for management like qsub - submit a job, and qstat - monitors the status. NTPD sets the network time protocol to synchronise the system.

The Remote Shell enables the MPI, LAM and PVM for node to node communication; in this instance the message passing with the MPICH is used in the system.

To implement parallel programming on the ELIHE HP homogenous cluster, the MPI (Message Passing Interface) package (included in the library of CLIC) was used.

5.1 MPI in ELIHE cluster

MPI is not a new way of programming parallel computers, but an attempt to collect the best features of a variety of message-passing systems developed previously such as Parallel Virtual Machine (PVM -- de facto standard before MPI) improve them, and standardise them. MPI is a library of functions and macros that can be used in C, FORTRAN, and C++ programs. MPI is intended for use in programs that exploit the existence of multiple processors/processing nodes by message-passing.

Initially, by 1994 each manufacturer had developed their own MPI with a wide range of features, often incompatible with one and other. There are a number of versions of the MPI standards, MPI-1.0, MPI-1.1, MPI-1.2 and MPI-2. The significant change from MPI-1 to MPI-2 was the addition of parallel I/O [12].

MPI has achieved one of its goals, adding credibility to parallel computing. The main goal of MPI was to achieve a degree of portability across different machines, homogenous or heterogeneous.

Message passing source code can be executed on an assortment of machines but only if the MPI library is available, while some change could be required to take best advantage.

MPI addresses the message passing model. It was designed to promote the overlap of computation and communication, benefiting by using the intelligent communication agents that enables it to hide communication latencies. This is carried out by non-blocking which separates the start of a communication from its completion.

In the message passing model of parallel computation, communication occurs when a portion of one processes address space is copied to another processes address space. This is a cooperative operation; after the first process executes a *send* operation, the second executes a *receive* operation (point-to-point communication). There are a variety of communication modes in point-to-point communication. In addition a send or receive may be *blocking* or *non-blocking*.

A blocking send or receive does not return from the subroutine call until the operation is completed. The send call blocks await the send buffer with the purpose to be reclaimed or vice versa, the receive function blocks until the receive buffer can be reclaimed. The

receive buffer actually contains the contents of the message.

Deadlock is a problem that can be surmounted in the buffering system of blocking. This must be overcome in the writing of the applications, which should not deadlock if copying is avoided, it is not really necessary and by ensuring the memory is available to allow progress in the communication. Blocking known as blocks is only the issuing of a thread which permits another thread to be scheduled. The blocked thread will be rearranged when the blocking call is approved.

An alternative method that usually results in a better performance is the non-blocking way of communication. The non-blocking post-send initialises a send operation, however it is not completed. The post-send will return before the message is copied out of the send buffer. MPI also includes routines for collective communication such as broadcast, gather and scatter and reduction operation.

The programs written in Fortran, C, C++, and recently in Java are compiled and linked with the MPI library.

There are five steps to create a parallel program in MPI:

- Include MPI libraries
- Initialise MPI environment
- Do job
- Perform message communication
- Terminate MPI environment.

CLIC comes pre-installed with MPI/MPICH 1.2.5 built into the system and has a built in suite of testing programs, hence we have used MPICH 1.2.5 version of MPI on our ELIHE cluster.

The name MPICH is derived from MPI and Chameleon both, because MPICH is versatile and can run on a wide range of environments as the initial implementation of MPICH uses the Chameleon Message-Passing portability system. The MPICH implementation comes with a variety of tools for building, running, debugging and analysing MPI programs.

This CLIC Mandrake middleware also contains MAUI that is an advanced batch scheduler and resource manager with a large feature set for high performance computing (HPC) PC clusters systems. It uses forceful scheduling policies allowing it to optimise, utilise and minimise job response time. It simultaneously provides widespread administrative control over resources and workload allowing a high degree of configuration in the areas of job prioritisation, scheduling, allocation, fairness, and reservation policies. MAUI's QOS (Quality of Service) allows directed delivery of resources and services, policy exemption, and controlled access to special features. MAUI also possesses a very advanced reservation infrastructure allowing sites to control exactly when, how, and by whom resources are used.

MPICH runs on a number of worker nodes specified in the machine file. This file was edited in CLIC to stipulate node rank.

MPI utilises C, C++ and FORTRAN77 and FORTRAN90 as bindings, illustrated in the following example:

- mpicc –o hello.mpich hello.c

(hello.c is source code programmed in C)

- mpirun – np 4 hello.mpich

The above compilation and run instructions will compile the source code in file hello.mpich that can run on 4 nodes.

Similarly to compile and run FORTRAN77 program the following instructions are used

- Mpif77 –o hello.mpich hello.f (hello.f is written in FORTRAN77 programming language)
- mpirun – np 4 hello.mpich

The list of available nodes for a particular run can be specified in the machines file as:

- mpirun – np 4 –machinefile machines hello.mpich

where ‘machines’ file contains the host names of worker nodes in the cluster.

5.2 Java MPI

As outlined above, MPI library specifies the names, calling sequences, and results of subroutines to be called from FORTRAN programs, the functions to be called from C programs, and the classes and methods that make up the MPI C++ library. These languages are traditional High Performance Computing Languages. Java programming language was not considered initially in the MPI library suite. Currently, there are efforts towards the design of MPI interfaces for Java [13,14,15].

The implementations of MPI for Java follow one of the following approaches:

- Use of Java Native Interface (JNI) to invoke routines of the underlying native MPI that acts as the communication medium,
- Implement message passing on the top of Java RMI – remote method invocation of distributed objects; or

- Implement high performance MP in terms of low-level ‘pure’ Java communications based on sockets.

Using the results of the above work, we have decided to install the mpiJava 1.2.5 together with JDK1.4.2 on our ELIHE cluster. This version of **java** oriented message-passing programming, to our knowledge was never tested before on CLIC Mandrake cluster.

Prior the installation of mpiJava 1.2.5 we have installed Java Developer Kit JDK1.4.2 (for Linux), and added the Java JDK /bin directory to our path setting so that mpiJava/configure script can find java, javac and javah commands.

The mpiJava interface was subsequently installed.

The mpiJava version 1.2.5 package provides an object-oriented Java interface to the MPI standard. It includes the Java Native Interface (JNI) C stubs that bind the Java interface to MPI C interface, which is MPICH 1.2.5 on ELIHE cluster. The software also includes a test suite of programs for Java interface.

6. ELHE Cluster Management and Maintenance

Protocols for fast Message Passing Libraries (PVM an MPI) have impacted the networking performance. Ganglia helped performance analysis and evaluation of our cluster, a monitoring and profiling tool with other patches. It was used to measure performance prediction and modelling.

‘Systest’, an MPI program, tested the network in order to analyse ELIHE cluster performance.

Unfortunately this version of CLIC did not work properly with cluster security, but it has reliable tools for managing the clusters. The system has the facilities to job and resource management in this high performance cluster system.

7. ELIHE Cluster testing

The system was tested using on MPICH and MPI. As outlined previously, MPI is a platform and compiler for a range of languages that allows communication between the nodes running in parallel on a distributed memory system. MPI has a library of routines that can be called from FORTRAN or C programs. MPL's (Message Passing Libraries) is portable as MPI has been implemented in every distributed memory architecture and it is optimised for the hardware it runs on. This is used in conjunction with MPICH - a portable implementation of MPI, a standard for message passing for distributed memory applications. In order to test the system, several parallel coding programs were used.

The initial testing of the cluster was carried out using the MPI/MPICH, this included a simple ‘hello world’ program, a pi constant calculation, a time stamp program, a matrix manipulation program, etc. Some of the programs were incorporated in the MPI package MPICH1.2.5 or 1.2.6. Also, available in this software is LAM testing. However, emphasis was on the MPI Suite.

A number of tests were performed on our cluster. If the cluster is ready to run, a "Hello World" message will appear for each node on running the program.

Run the mpirun command as follows:

Homogeneous Running mpich version "Hello world"

[terence@enterprise user]$ mpirun -np 4 ./test_mpi.mpich

node 0 : Hello, world
node 1 : Hello, world
node 2 : Hello, world
node 3 : Hello, world

OR alternatively:

Heterogeneous machines running lam version "Hello world"

[terence@enterprise user]$ mpirun-lam -np 4 ./test_mpi.lam

node 0 : Hello, world
node 1 : Hello, world
node 2 : Hello, world
node 3 : Hello, world

This was completed successfully along with several other test programs. The hardware was shown to be working using a Ping test and the Ganglia Monitor benchmarking tool [9] as seen in figure 2 bellow.

Figure 2. Screen dump from the Ganglia Monitor

Similarly, Java MPI programs were tested. An example of compiling and running Java programme on 4 machines is as follows:

javac Hello.java

prunjava 4 Hello

The ‘prunjava’ script is a wrapper for the various MPI run commands, specifying the number of processors/nodes on which the program will be executed (4 nodes in the above example). It dynamically creates a script that sets up the required environment and invokes the ‘java’ command. A list of available worker nodes can be given in an MPICH-

style ‘machines’ file in the local directory (see above section 5.1). Our tests have proven that the choice of the mpiJava1.2.5 and JDK1.4.2 packages leads to successfully implementing the Java programming environment on our cluster, along side C, FORTRAN and C++.

8. Summary

The initial objective of our project - building the ELIHE cluster to design and implement a HP cluster for teaching parallel computing architectures in the School of Science and Technology and to promote the use of high performance computer technology for research to faculty members and students, has been achieved. Results of our initial work were published at the Cluster 2005 conference in Boston Massachusetts [16].

To complete this project it was necessary for one to be a ‘jack of all trades’, as it required knowledge of computer hardware, computer networks, operating systems, knowledge of parallel programming using MPI/MPICH and various types of programming languages e.g. C, C++, FORTRAN and Java.

A range of programming environments were installed and tested on the cluster, providing a benchmark for programming in C, C++, FORTRAN77, FORTRAN99 and Java.

The ELIHE HP cluster will remain solely dedicated as a resource for teaching and research, and is expected to be used by students and staff in the future.

This is a new area that is currently under scrutiny by world computer scientists and it is important to document the ability of the system to solve problems that have a lot of computations and data.

9. Future work

The School of Science and Technology in ELIHE has recently acquired 16 Pentium D processor based computers, housed in a dedicated cabinet. Once the preliminary tests and installation are carried out, there is a choice of cluster middleware software to be made and implement onto this bank of PC’s.

The next phase of our project is to build a High Availability and High Performance Linux cluster using acquired Pentium D machines, Gbit Ethernet network and possibly replacing CLIC Mandrake with OSCAR or ROCKS middleware software.

When the CLIC and OSCAR cluster software have been tested, the choice will be made as to which is the most suited for the applications the East Lancashire Institute for Higher Education (ELIHE) needs.

The implementation of the ROCS or OSCAR (HA and HP) cluster and the existing CLIC cluster will provide an opportunity to explore Grid technology in our school.

Once this is completed we will be running comparison tests on the individual clusters and furthermore we will be linking both systems together.

This can be used to create a part of ELIHE Grid Computing system. A cluster integration in grids creates a network based distributed computing - a ‘cluster based grid services’.

In the mpiJava 1.2.5, installed on ELIHE cluster, Java wrappers were automatically generated from the C MPI header using Java-to-C interface generator (JCI). This eases the implementation work, but does not lead to a fully object-oriented API.

For our future work we are planning to implement Message Passing in Java (MPJ), and compare the transfer times and bandwidth with mpiJava, MPICH and LAM/MPI.

Further testing of the cluster would prove that clusters are the economical and functional way for testing such things as:

- Scientific Applications
- Data Distribution and Load Balancing
- Algorithms for Distributed Applications.
- Innovative Cluster Applications
- Scalable Internet Services on Clusters using Ganglia

The Clusters will be used in the delivery of the computing and engineering programmes in the ELIHE as well as supporting the research of our staff in engineering simulation and modelling.

Due to the successful ELIHE HP cluster implementation the ELIHE has decided to assist in funding of a design, development and implementation of ELIHEII cluster and support involvement of the local community who can benefit from the HP and HA clusters performances.

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BSc/MSc Computing at ELIHE

The BSc courses at East Lancashire Institute of Higher Education (ELIHE) at Blackburn College are validated (and awarded) by Lancaster University.

ELIHE now offers BSc Computing in the following streams:

BSc Computing

On this course you would specialise in the *Ordinary* (second) year on topics including Formal Computer Science, Programming a Distributed System and Databases and in the *Honours* (final) year on topics such as Object-Oriented Development and the Unified Modelling Language (UML), Programming Languages, Formal Specification and Compilation. Java is the main programming language that is used.

BSc Computer Systems Engineering

On this course you would specialise in *Ordinary* (second) year on topics such as Computer Systems Architecture and Computer Communications and in the *Honours* (final) year on topics such as Parallel Computer Architecture and Mobile Communications.

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On this course you would specialise in *Ordinary* (second) year on topics such as eCommerce and Databases and in the *Honours* (final) year on topics such as Object-Oriented Development and the Unified Modelling Language (UML), Intelligent Agents and Mobile Communications.

The BSc can be taken part-time or full-time and can be entered at any level, subject to the qualifications, experience and aptitude of the applicant. If we think of the BSc as a three year full-time course the first year is about equivalent to a HNC/D, the second year is equivalent to a BSc(Ord) and the third year is equivalent to the BSc(Hons).

Entry to the first year usually requires 160 UCAS points, otherwise applicants are normally advised to start off on a HNC/D qualification. For entry on to the BSc (Ord) you should have a HNC with at least an average merit or a HND with at least 6/16 merits. (Note that a Distinction counts as two merits.). For entry on to the BSc (Hons) (third year of a standard degree) you should have the equivalent of a BSc(Ord), but we would also consider an alternative entry to bridging (fast-track) to the BEng(Hons) for students with an excellent HND.

The normal delivery of each module is usually a 3 hour or 3.5 hour lesson each week for a semester (about 4 months). Classes are normally held in the morning (9:00-12:30), afternoon (1:00-4:30) or in the evening (6:00-9:00).

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The East Lancashire Institute of Higher Education at Blackburn College

Academic Report: AR-07-07

Perceptions of Crime in Blackburn Town Centre

Barry Powell[1]

July 2007

Criminology Research Group

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East Lancashire Research 2007, pp 67-78.

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Perceptions of Crime in Blackburn Town Centre

Barry Powell[1]

Academic Report AR-07-07. East Lancashire Institute of Higher Education, Blackburn, UK.

I. INTRODUCTION

The report is a continuation of East Lancashire Institute of Higher Education's policy of linking coursework for many of the HND, Foundation and Undergraduate degrees to local employer needs. We are pleased that we at the college have been asked for the fifth successive year to undertake the study. The added bonus this year was payment for the survey which has benefited research funds in higher education. We are pleased that the work of the students has been recognised in such a manner.

This year students were once more required to gather data on public perceptions of crime and community safety in Blackburn town centre. Like last year the group undertaking the research were level 1 (first year students) as opposed to level 2 (second year students). The reason for this change is that the exercise is better suited to the first year modules students undertake. This in itself creates issues as it is one of the first pieces of work undertaken by the students. However, most students committed themselves undertaking research in some atrocious conditions, this I can vouch for as I got very wet as I wandered around town making sure the data collection was progressing satisfactorily. Due to weather conditions the sample population was smaller than expected but this was down to the time of collection (December and January) and the aforementioned weather conditions. Can I take this opportunity to offer my thanks to the HND Year 1 Criminology students who completed the assignment for their efforts in putting this piece of work together and to Vicky Clark and all at Community Safety Partnership for their support.

II. LITERATURE REVIEW

One of the aims of the 1998 Crime and Disorder Act was to create multi agency partnerships to reduce the incidence and fear of crime (McLaughlin and Muncie 2000 in Clarke, Gewirtz and McLaughlin). Indeed, this survey it could be argued as a result of this act. However, there seems to be some unresolved issues. For example how do local community safety partnerships undertake meaningful evaluation of their work? This can be a methodological nightmare as any general research methods book will confirm (see Smith 1998 as an example). Yet such work can have a practical use and cost. For example Hough and Tilley (2004: 19) suggest that a thorough going evaluation of Community Safety Programme (CSP) work could cost up to £20,000. Yet the Home Office Crime Reduction Programme should be 'cost effective' according to a report prepared for that now historic department (Homel et al 2004: 18). This seems to suggest that inter agency working to prevent crime was not at the top of priority list. Instead, it is being seen to be doing something and controlling costs that are at the forefront of the agenda when using a multi agency approach (Burnett and Appleton, 2004).

An example of the latter point is something borne out by the work of Radford and Gill (2006: 376) who note the problems of getting domestic violence on the community safety agenda and by Norris and McCahill (2006) whose study of CCTV operators at a private shopping mall noted a dissonance between workers, Mall management and police. Thus, the implementation of community safety and crime prevention does not always run smoothly. This survey has always had a tight if limited remit; it ascertains the perceptions of the public and crime in Blackburn town centre. It is a manageable project that contributes to the community safety partnership. Evaluating the development of issues ascertained by the survey is something that the project and the violent crime reduction group are now probably ready to debate. Indeed, as the academic evaluation studies mentioned earlier assess organisational issues that can prevent fluid multi agency working and using the intelligence gathered in respective fields, making the leap from having the descriptive figures in this report and using them more critically is something that could well be developed. These are issues the group might like to discuss before embarking on next year's questionnaire.

Looking at issues that have come up in previous years, the worries over changes in opening hours of drinking establishments do not seem to have materialised although

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worries about public health due to 'binge drinking' remain evident. The direction and ever increasing politicisation of the criminal justice system has also lead to a shake up in the delivery of government provision. There is without doubt a confused arena with what is to be measured, how it is measured, the relationship between the partner agencies and fear of crime needing to be discussed so that developments in this study can take place in order that it keeps its relevance.

III. METHODOLOGY

The questionnaire format has enabled a reasonable amount of data capture. As with previous questionnaires the questions are designed to elicit people's perceptions of crime and the fear of crime in Blackburn Town Centre. Due to the evolutionary development of the survey comparison between years can be made. This enables comparison for the reliability of the data although questions about the validity of the survey are another matter (Hough and Tilley, 2004: 19, Yates, 2004: 31). Indeed, the questionnaire method gives answers to questions the researcher has set and may circumscribe issues relevant to the respondent.

This year two slight changes were made to the questionnaire. One was to include a question about public knowledge of the Safe Haven Bus which at the time of data collection was about to take to the streets. The second request was to add taxis to the list of responses on public transport for questions 6 and 18 at the request of representatives from the licensing department. As with last year the rubric for collecting data was rigorous and ensured the reliability of the data. The method of using a protected Microsoft excel spreadsheet to which the only things that could be added were the collected number of responses to each category of answer once again proved useful. Of course validity is still an issue here. Our respondents this year were far more difficult to get due to weather conditions. Indeed, at one stage, the only significant numbers of people available were in the vicinity of the college.

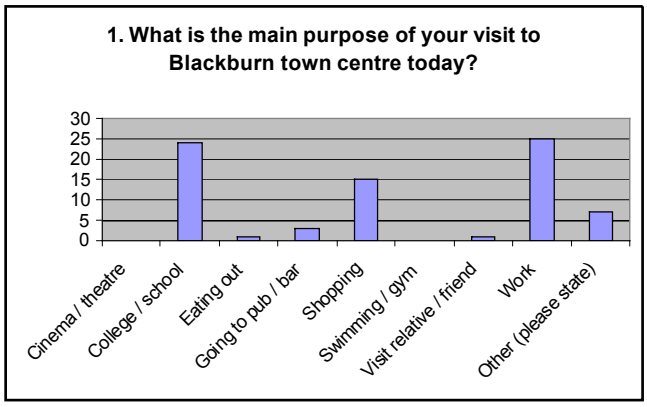
A discussion that will be developed as the report continues is how to take the data found and relate it to some practical ways and methods of ensuring greater community safety and how to review the parameters of the current survey. Indeed, it may be that the data collection methods and study are mature enough to enable a significant change of structure and even a change of method of collection. In addition some of the policies that have been activated in the town centre may have lead to displacement to outlying council wards; this may be an area for further investigation.

To conclude this section the questionnaires were issued in November 2006 and the data gathered in December 2006 and January 2007. The compilation of the data was undertaken by me in March/ April of 2007 with final reading and editing taking place in May 2007. Any faults in the final compilation lie with me as editor.

IV. RESEARCH FINDINGS

Question 1

What is the main purpose of your visit to Blackburn town centre today?



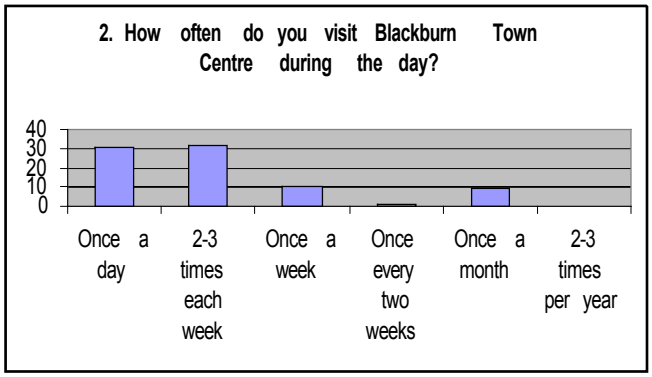
Discussion

Most of the respondents were in the town centre as college students or working. This year a lot of the surveys were conducted in and around the college due to the fact that this was the most populated area given the poor weather conditions. Normally those in around college make up between 10 and 20% of the responses, this year it was 25%.

Question 2

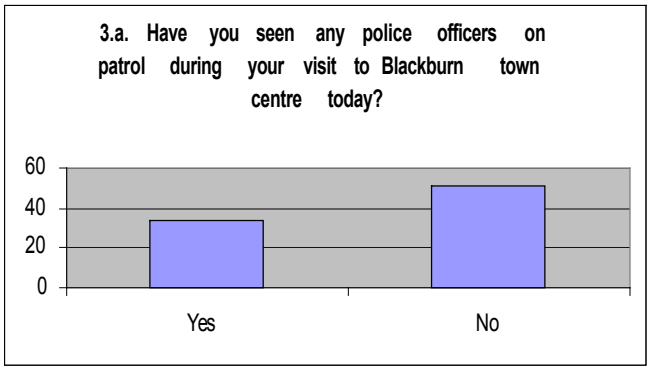
How often do you visit the Town Centre during the day?

Most of those questioned (88%) attend the town centre regularly. This may point to the town centre being used in a utilitarian manner rather than a place that attracts visitors. This it is suggested has some bearing on the shape of the economy of the town centre



Question 3. a.

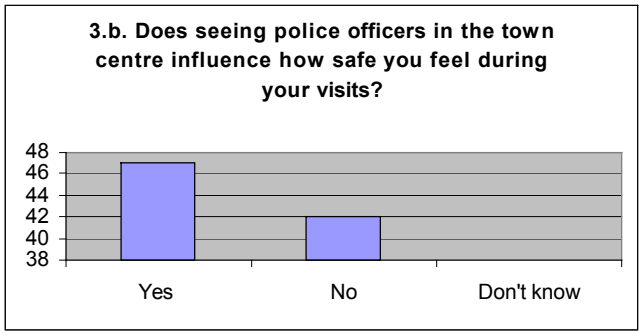
Have you seen any police officers on patrol during your visit to Blackburn town centre today?



Only 42.5% recalled seeing a police officer on the day. However, while down on last year there were also less people on the streets due to the weather conditions that most questionnaires were collected in. This is the lowest figure since the survey began.

Question 3 b

Does seeing police officers in the town centre influence how safe you feel during your visits?



Main

53% of those questioned feel that police officers influence how safe people feel during their visit. However, there may be an issue over the wording of the question here as we do not know about what sort of influence the police have on those visiting. For example, and as previously pointed, out seeing more police officers might leave some feeling worried about the town centre environment with fear that police are visible on the streets because of some crime and disorder issues. Yet we would not know this from the question.

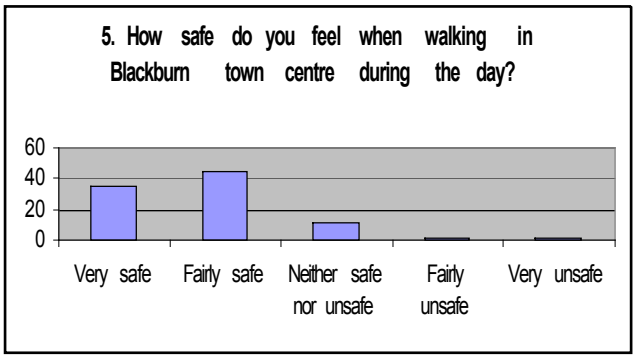
Question 4

Have you seen any security officers in the shopping centre, 'the Mall' today?

Only 50% of the sample had seen a security officer at the Mall. But this needs caution as due to the weather conditions when collecting the sample most of those interviewed might well have not ventured to the Mall. The bare figure is again like the similar question posed about the visibility of police officers and the lowest positive response since the survey began.

Question 5

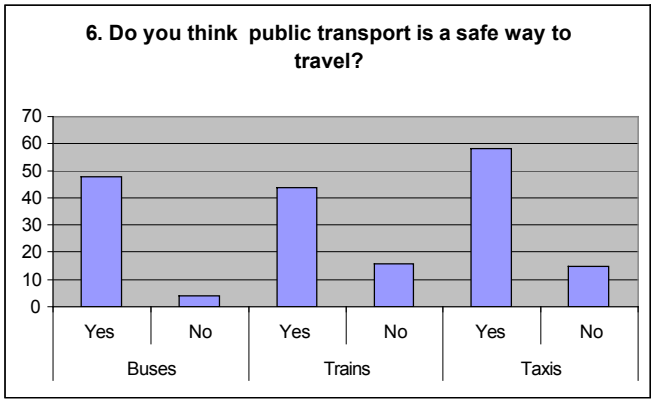
How safe do you feel when walking in Blackburn town centre during the day?



This question has been worded slightly differently and it depends on how you want to interpret what is here. However, some 97% are free from being unsafe (2% up on last year's figure) with 85% stating they feel very or fairly safe. This corresponds favourably when compared with statistics from previous surveys.

Question 6

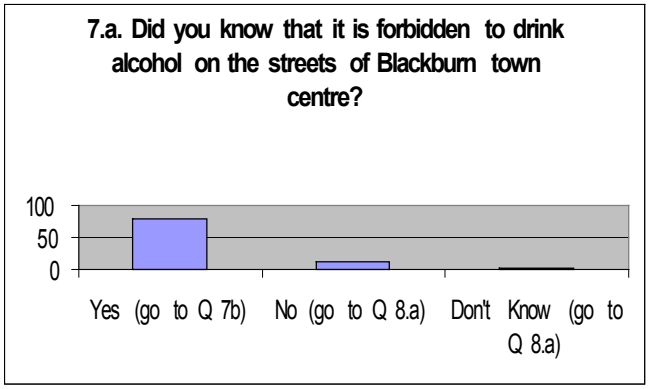
Do you think public transport is a safe way to travel?



By and large buses were seen as safe while taxi and trains felt less safe according to the survey; this is the first time taxis have been included in this question.

Question 7.a.

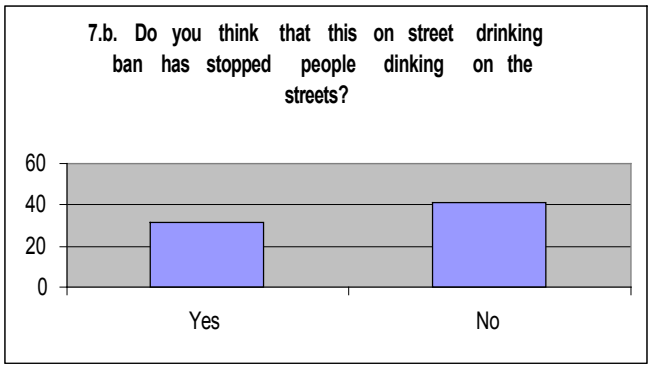
Did you know it is forbidden to drink alcohol on the streets of the town centre?



85% of this year's respondents knew it was illegal to drink on the streets of Blackburn. This shows an increase on previous years and if repeated would indicate that message about the ban is being received by the public. A comparison here is 70% of those who responded to such a question in 2005 knew of the ban.

Question 7.b.

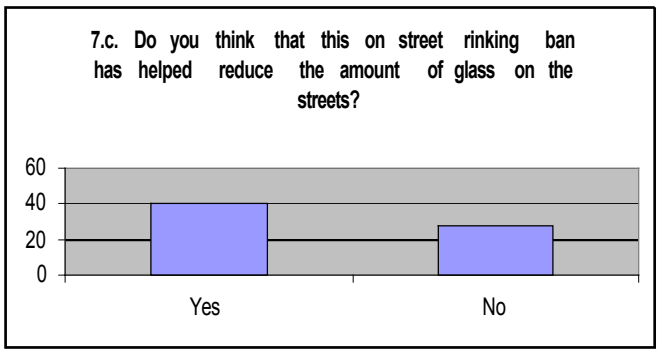
Do you think this on street drinking ban has stopped people drinking on the streets?



43% of respondents in this year's survey thought that the ban prevented street drinking. While up on last year it is down when compared to 2004's total of 56%. This is the highest figure for 'no' since the survey began.

Question 7.c

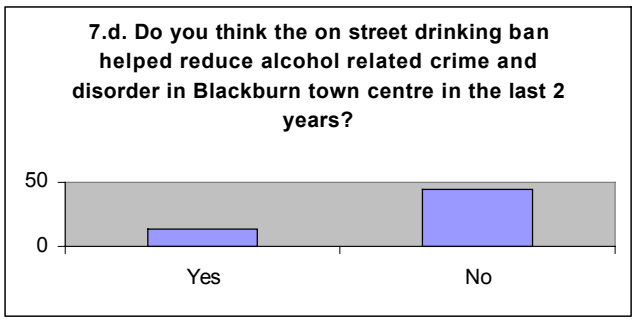
Do you think this on street drinking ban has helped reduce the amount of glass on the streets?



What has been consistent over the years is that the ban, it is believed, has led to less glass on the streets. In this year's survey 59% thought the ban had reduced glass in public places. However, it could logically be argued that public street drinking is evaded by those using plastic bottle and cans to drink alcohol publicly. It may also point to an effective street cleansing services in the town centre. The response is in line with previous years.

Question 7d

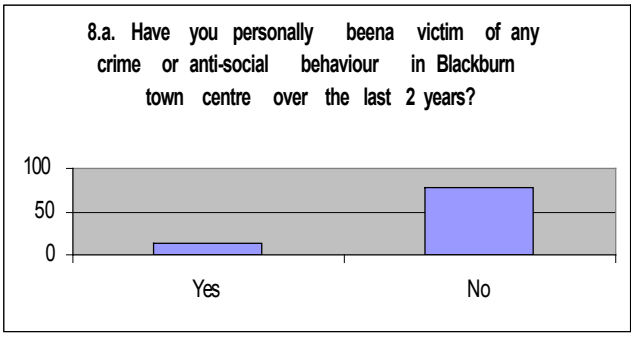
Do you think the on street drinking ban helped reduce alcohol related crime and disorder in Blackburn town centre in the last 2 years?



A big fall here with lower percentage (24) saying yes to the idea that the ban in street drinking has led to less alcohol related crime than last year (36%). Again the lowest figure since the survey started on 2003.

Question 8

Have you ever been a victim of any crime or anti-social behaviour in Blackburn town centre over the last 2 years?



Of those asked who responded 15% (14 out of 92) said they had been a victim of crime or anti social behaviour in last 2 years. This is a similar response rate to a slightly differently worded question from 2005 and in line with responses from 2003 and 2004.

Question 8.b

If yes-are you willing to say what type of crime or anti social behaviour you were a victim of?

8.b. If yes, are you willing to say what type of crime or anti social behaviour, you were a victim of?

	Not comfortable saying	3
Crimes	Assault	4
	Damage to vehicle	1
	Car broken into	
	Car stolen	1
	Robbery	
	Sexual assault	
	Other	

Anti-social behaviour	Vandalism	1
	Litter/rubbish	
	People using/dealing drugs	1
	People being drunk and rowdy	1
	Insulted	2

Here a tabulated list has been inserted showing assault as the most serious mentioned crime.

Question 8c.

Are you willing to say whether you reported the crime or incident to the police or other relevant organisation (e.g Local Authority)?

Out of the 14 who stated they had been victims of crime 9 had reported it to the police.

Question 9.

Are you aware of any of the following crime prevention/ community safety schemes in Blackburn town centre?

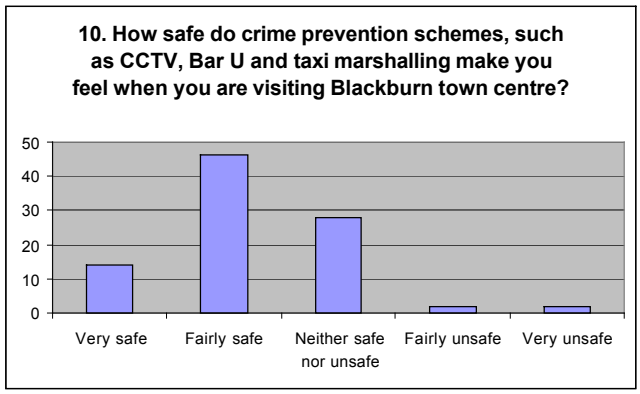
CCTV	Yes	83
	No	2
	Don't Know	7
Bar U scheme	Yes	37
	No	47
	Don't Know	8
Taxi Marshalling Scheme	Yes	32
	No	53
	Don't Know	7

Again the table rather than the graph is being used here as it provides clearer information. While nearly all know of the CCTV scheme less than half know about Bar U or the taxi marshalling scheme. Both the taxi marshalling scheme and Bar U registered with about a third of our respondents as opposed to either half or nearly half knowing last year.

Question 10

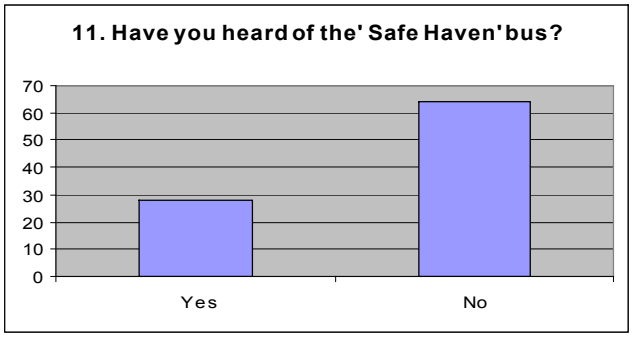
How safe do crime prevention/community safety programmes, such as CCTV, Bar U and taxi marshalling make you feel when you are visiting Blackburn town centre?

As with the question on safety it all depends on how you wish to interpret the data. If you are positive you can say that 96% of people suggest that the above schemes take fear out of the equation when visiting the town centre. 66% feel very safe or, fairly safe because of crime prevention schemes.



Question 11

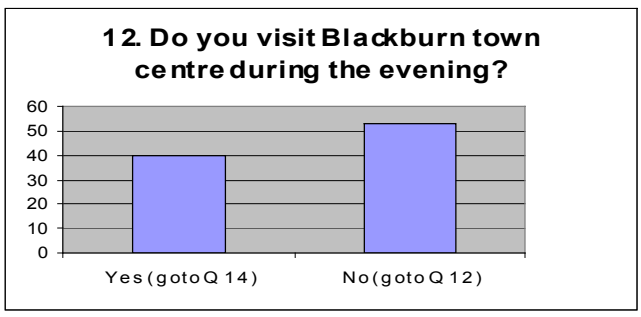
Have you heard of the Safe Haven bus?



A brand new question and one added just as the bus was about to be brought onto the streets and answered by most in the first few weeks of its inception. Around 30% had heard of it at this stage. This sets a mark for which the bus can be measured next year.

Question 12

Do you visit Blackburn Town Centre during the evening?



40 out of 92 responded that they visited the town centre of an evening. This is down when compared to previous year.

A response in the region of around 60 out of 92 would have been expected. The fact that a lot of respondents were college students might suggest an even higher figure. However, the number is significantly lower than would be expected.

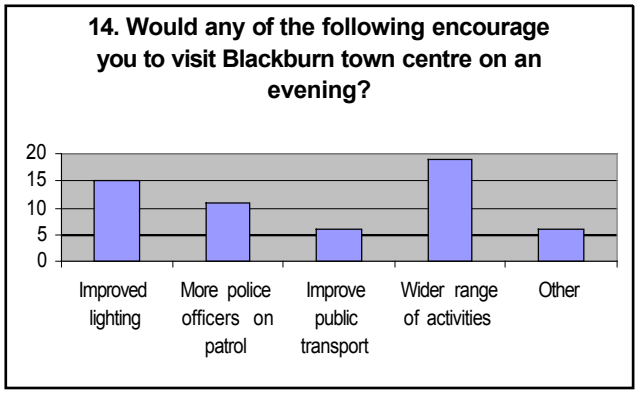
Question 13

<u>If you do not visit Blackburn town centre in an evening, can you please tell me why?</u>

The most popular responses here were:
Shops are closed. Busy. Other commitments. Do not visit clubs or bars. Do not live here. No need to. Too many people /groups on the streets. No reason to. Live in Great Harwood. Under 18. Work in the evenings.

Question 14

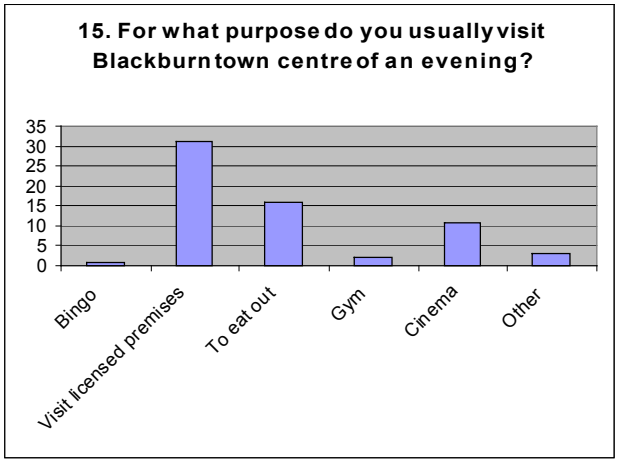
<u>Would any of the following encourage you to visit the Town Centre during the evening?</u>



As with last year a wider range of activities was mentioned more than any other alternative. Thus, the development of the night time economy to attract more than those just out for a night in vertical drinking establishment is raised.

Question 15

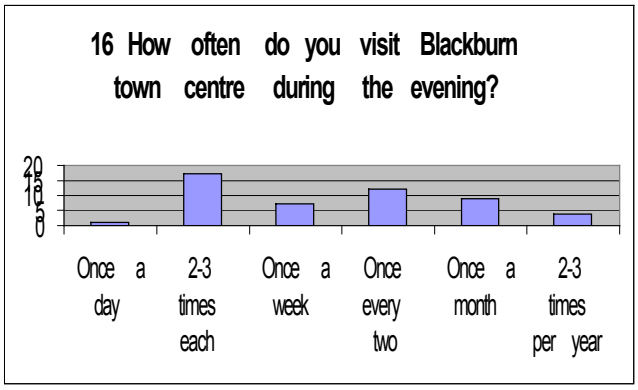
<u>For what purpose do you normally visit Blackburn town centre in an evening?</u>



As per usual respondents gave more than one answer to this question thus there are more replies than those who do actually come to Blackburn town centre of an evening. However, and unsurprisingly, licensed premises are the most visited.

Question 16.

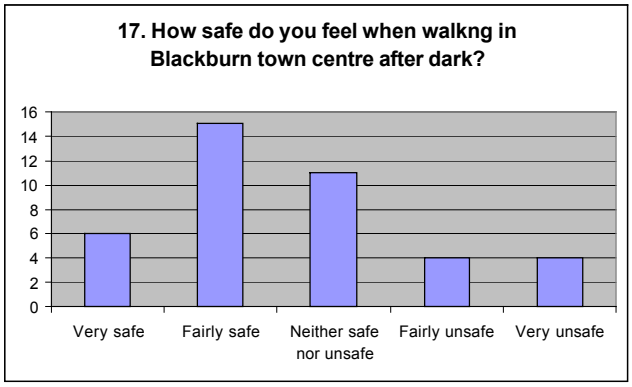
<u>How often do you visit Blackburn town centre during an evening?</u>



The most popular answer here is two to three time a week although roughly less than a quarter of the sample uses the town centre at last once a week during the evening.

Question 17

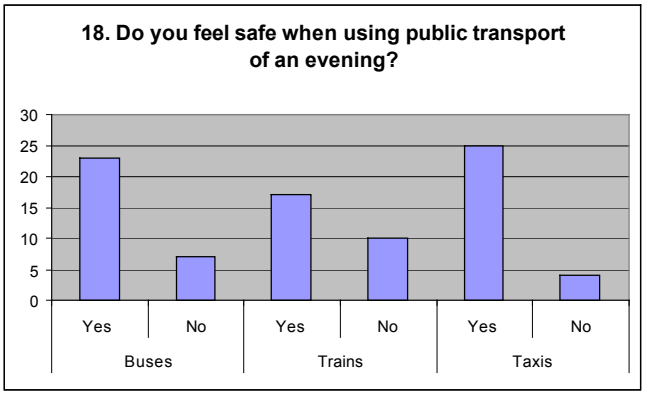
How safe do you feel when walking in Blackburn town centre after dark?



Of those questioned who answered 32 out of 39 felt free from harm in the evening. Remember this is a small sample but 80% felt free of fear. This is up 1% on last year's survey; this is 8% points higher than 2004 and 6% points higher than 2003. A note of caution again here is that those who do not feel safe may self police themselves by not going out at night. Thus the answers we have are from those who go out anyway.

Question 18

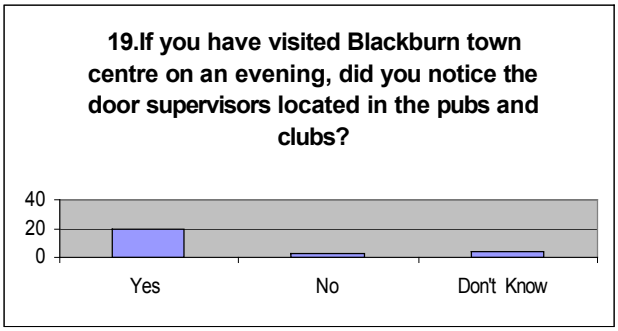
Do you feel safe when using public transport in the evening?



Taxis are seen as the safest mode of evening transport with 14% saying they feel unsafe as opposed to buses (23%) and trains (37%). However, the response for trains this year was better than last year when 47% of those who responded felt unsafe.

Question 19

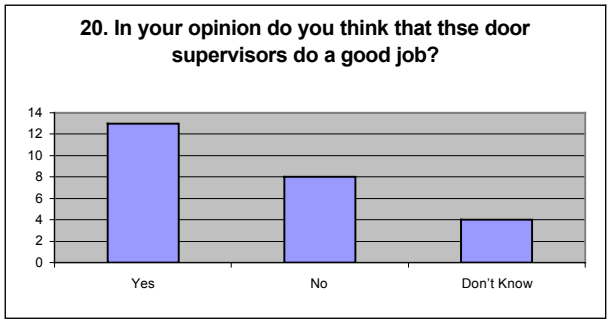
If you have visited the Town Centre in an evening did you notice the door supervisors located in the pubs and clubs?



Unfortunately only 26 satisfactory responses to this question with one group asking the question to those who do no go out at night (see question 12) therefore the whole of that batch of questionnaires were eliminated from this particular question. Only 1 did not notice door supervisors.

Question 20

In your opinion do you think these door supervisors do a good job?

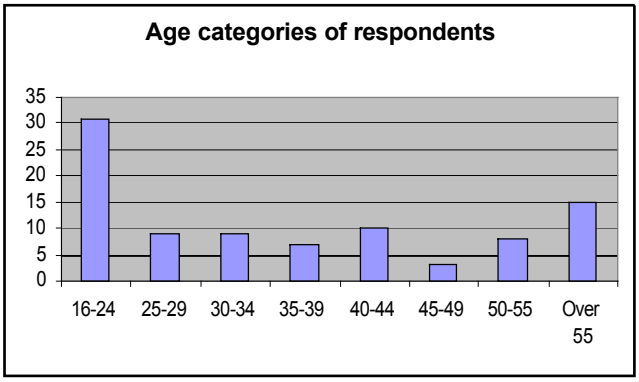


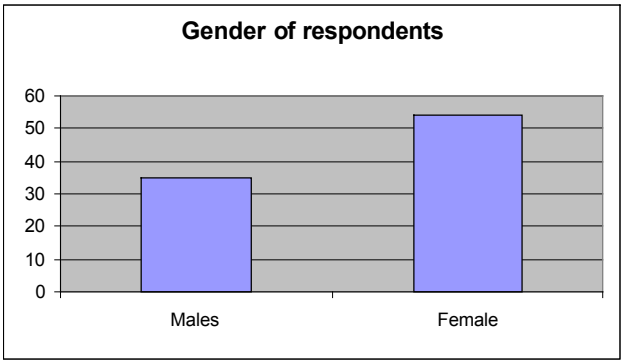
In a small sample only 50% of those who responded thought that door supervisors do a good job. This is similar to last year with the last two surveys showing a less favourable response than in previous years.

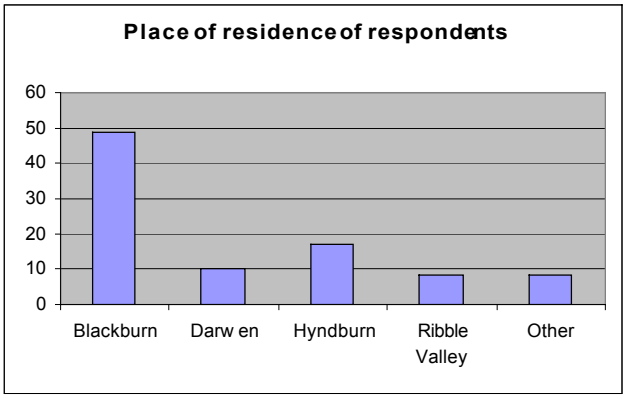
2007
Demographics

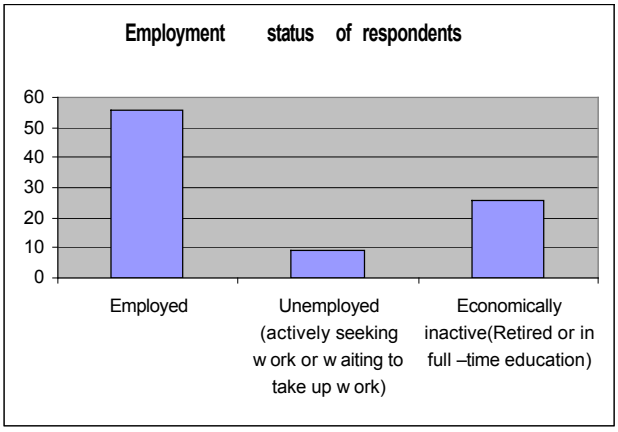
The survey was not weighted for age, social class, gender or place of residence. This leads to an unrepresentative cohort, however, given the time in connection with method

of collection this should not come as a surprise. When looking at age it is to be noted the survey interviews more from the 16-24 age group, that most surveyed were female and that British white was over represented in those questioned. Nevertheless the cohort shows similarities with other cohorts we have had in the past in terms of their responses and therefore should any shift in opinions occur it may well still reflect something about crime and disorder and the town centre.









V SUMMARY

The collected data can be summarised as follows:

- 97% are free from feelings of a lack of safety in the Town Centre during the day. 85% stated they feel either very or fairly safe.
- The incidence of crime in the town centre seems to be limited.
- The lowest figures recorded for sightings of police officers on town centre streets and security officers in the Mall.
- Once again while there is general knowledge of the street drinking ban there is diffidence as to how effective it is in the cessation of on street drinking. However, the majority of respondents, as with previous surveys, think the ban reduces glass on the streets of the town centre.
- Around 1 in 7 people mentioned that they have suffered either a criminal offence or due to anti-social behaviour.
- 80% of those visiting Blackburn town centre of an evening do so without a feeling fear.

The numbers of questionnaires collected was less than in previous years in large part due to the lack of available respondents due to the method of data capture. The method used, street interviews took pace at times of poor weather conditions.

V. CONCLUSION

This year the data collection method returned to being solely based on street interviews. As mentioned in several occasions this definitely affected the shape of responses. For example in such conditions the college, where there is a temporarily captive audience, lent itself to gathering more respondents than normal. In addition the ethnic make up of the group collecting the data lead to less than expected numbers from the Asian community responding. Thus, some of the conclusions may owe more to the weather than to the normal routine of the town centre. In addition the sample group for those how started to answer questions on the night time economy was even smaller. Forty started to answer with one ending the questionnaire before completion. Therefore there were only 39 full respondents to the night time economy section.

Taxis were included on the response to questions 6 and 18 and it seems they are seen as safe means of travel. There has been discussion of CCTV cameras in taxis but from the information gathered in this survey safety is not an issue.

There were low numbers of those who suggested they had seen either police officers or security officers. However, the numbers on the streets were minimal when these questions were being asked. In relation to town centre drinking we had the lowest number of positive responses for the question on whether the ban on town centre out of premises drinking led to less crime though with the perennial contradictory response that the town centre ban reduces glass on the streets. The corollary of this might well be that people think drinking is going on in the town centre either legally in pubs or on street out of cans and plastic bottles with resultant violence. This is something that might or might not be corroborated by police statistics. Indeed, it is something that could be looked at via a focus group of town centre users or by adding or rephrasing a question.

It might also be fruitful to develop the questions around door staff since it is a few years since the accreditation do such staff through the SIA (Security Industry Authority). For the last two years it is noticeable that those answering feel that door staff are seen in a less positive light than in previous years. This is something that could be followed up.

As illustrated there were issues in collating the data. This time the inexperience of the gatherers and the appalling weather conditions made for a less than smooth experience. The use of a smaller more experienced group of students who will be paid is to be experimented with next year.

VI. RECOMMENDATIONS

The following recommendations are made:

- Assess the development of the questionnaire and the methods of data collection.
- Analyse the responses to the question with regard police and security offers.
- Monitor issues concerning the town centre drinking ban.
- Assessing ways of using the questionnaire practically.

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the international, that stretch from the 17th century to the present, that look at people as well as institutions and forces and that above all else, are not just interesting but also fun!

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Foundation Degree in Complementary Medicine
Foundation Degree in Housing Studies
Foundation Degree in Neighbourhood Management
HNC/D Travel and Tourism Management
HNC/D Public Services
HNC/D Hospitality Management

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BTEC Public Services
BTEC Travel and Tourism
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A level Law
A level Psychology
A level Religious Studies
A level Sociology

For further information see the relevant web site; www.elihe.ac.uk or www.blackburn.ac.uk or telephone (Student Hotline: 01254 292929 Employer Hotline: 01254 292500)

The East Lancashire Institute of Higher Education at Blackburn College

Academic Report: AR-07-08

Modelling, Developing and Implementing Sub-Sea Power-Line Communications Networks

Javad Yazdani[1] Kevin Glanville[2] and Preston Clarke[2]

July 2007

Engineering Research Group

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East Lancashire Research 2007, pp 85-91.

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[2] eProduction Solutions

Modelling, Developing and Implementing Sub-Sea Power-Line Communications Networks

Javad Yazdani[1], Kevin Glanville[2] and Preston Clarke[3]

Academic Report AR-07-08. East Lancashire Institute of Higher Education, Blackburn, UK.

Abstract - **The development of suitable communication systems and the planning of power-line communication networks require models of the transfer characteristics of the mains network for that particular environment. Power-Line Communications (PLC) presents itself as an economical solution to the sub-sea and marine environment in comparison to Fibre Optics and others.**
This paper offers results of calculation, measurement and near real time simulation which justify and fulfils the performance requirement of the present sub-sea communications. The methodology is now part of an ongoing research to establish a unique and smart approach to the design of future sub-sea umbilical cables capable of transmitting data at higher frequencies.

INTRODUCTION

1. Background

The selection and installation of the initial sub-sea cabling infrastructure that also provides for signal communication will have a major impact on the performance of the system and the ability for future expansion of the sub-sea networks (ssN)*. This necessitates developing ssN that are generally extended (typically 10 to 30Km) point-to-point networks with groups of nodes at intersections. Detailed modelling of cable and the network topography to ensure trouble free operation is therefore the focus of our research**.** PLC over the Low Voltage Distribution Network (LVDN) and propagation characteristics of mains cabling in the High Frequency (HF) range have been examined in our early research stage and results indicate it's suitability in the 1-30 MHz range.[2][3] An opportunity therefore exists within the sub-sea environment to examine and utilize high frequency communication above 1MHz, there is a need to understand the behaviour of the signal and power that travels along the cable in the way it changes due to electromagnetic effects in a sub-sea environment. Typical problems to be addressed include attenuation, dispersion, distortions, and crosstalk.

2. Aims and Objectives

Primarily for the next stage of this project we intend to repeat our tests to date described in this research paper in sub-sea environment, demonstrating technical feasibility for higher frequencies in HF around 1-30 MHz. The outcome will probe into the application potential and user acceptance; also provide the design data to determine cable sizing and help to devise a modelling strategy that match our requirements. This approach will ensure optimum system performance at the desired frequencies in the presence of impulsive noise interference and cross talk effects. Finally, it will offer efficient tools for the simulation of cables in a sub-sea point to point network. The methodology will help to develop analytical models to evaluate, verify and compare the performance results with those obtained from the simulation trials.

3. Standards

The present power-line carrier for sub-sea has so far concentrated on transmission and reception in the low frequency band using the European Committee for Electro-technical Standardization, CENELEC, EN50065, which covers the communications requirements for transmitting and receiving signals over the LVDN, through the umbilical cable for communication, in the frequency range 3 kHz to 148.5 kHz. The signalling level for general use is limited to 116 dBμV (Class 116 equipment), and for industrial and marine to 134 dBμV (Class 134 equipment). Generally for sub-sea where cable runs are less than eighth of wavelength and communication is through a single power phase, the presence of low impedance loads allows wire inductance to dominate. Although attenuation is a concern for impairment and signal loss, at low frequencies, the receiver gain can often overcome this loss. Sub-sea cables are initially designed with power in mind, the specification data available in sub-sea cabling is not typically suitable for communication characteristics. In this environment the electrical power systems are traditionally laid up with a combination of hydraulic and chemical hoses in a continuous umbilical of lengths of up to 30Km. Interconnections between cables and nodes are achieved by using sub-sea wet-mate-able connectors.

Utilizing communication on power strategies limits the size, complexity and cost of the sub-sea umbilical. We further emphasize that during system design it is necessary to consider current and future system loading; including likely topography, to confirm end device matching requirements in addition to cable sizing. Detailed cable data for the desired frequency is typically not available at the design stage; this situation is further exasperated due to the cable stock not being present owing mainly to the "build to order strategy" for sub-sea cables/umbilical.

We believe the signal integrity will be increased by building a transmission line model in order to perform a simulation on the sub-sea cable similar to the model build for

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[3*] Design & Application Engineer *eProduction Solutions*

low frequency. The model will simulate and perform an electromagnetic (EM) field analysis to generate accurate L, R, C, G cable transmission line models. Thus enabling suitable tuning of the system to optimise and confirm the performance that can be achieved.

It is commonly agreed that the power-line network proves to be particularly inhospitable when operating as a transfer medium in the area of 1-30 MHz; we further agree that its transmission behaviour displays considerable frequency dependence. Power Line Analysing Tool (PLAT) [1] introduced a mathematical model using the transmission line theory for obtaining the characteristic impedance of the power-line channel where the model was used to evaluate the performance of power-line communication systems in a frequency band between 1 and 30MHz. PLAT simulator allowed a parametric model in the considered frequency range describing the heterogeneous transfer function of a power-line link to be realized. Amplitude and phase response of low voltage power-lines and issues like input impedance, phase constant, attenuation and distortion were addressed. Figure1 shows amplitude and phase response of a single load respectively.

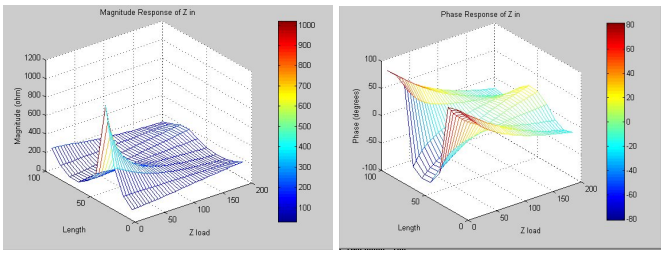


Figure 1 A Single load magnitude and phase response

Various other theoretical and practical models of the power-line have since been introduced each offering merits for a particular approach; however there is no development in general yet that has been offered and/or adopted for sub-sea cables, that would precisely specify the line's transfer parameters. These parameters are ingredient knowledge necessary for umbilical manufacturers prior to design and production of umbilical electric cables.

The USA frequency band covers the frequency range 45 kHz to 450 kHz. This study starts by evaluating technology used to date and to highlight new methodology to model and develop tools as a guide for existing communications in a sub-sea environment. As the sub-sea well networks extend, the need for improved efficiency and capacity in terms of communication system data throughput are increased.

4. Typical Sub-sea Control System

A sub-sea control system is usually considered to allow an operating field to be extended and tied back to an existing platform facility Figure 2.

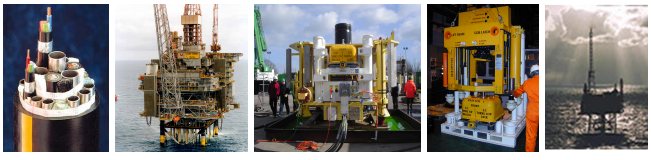


Figure 2 A Typical Oil Field and a SCM

The host platform for the sub-sea control system may typically be located up to 30Km from the wellhead. For this type of development an electro/hydraulic multiplexed sub-sea control system is tied back to the platform by means of an electro/hydraulic control umbilical. When installing a sub-sea system a composite electrical and hydraulic umbilical is installed to provide hydraulic and electric power to the sub-sea control module. Reliable communications are provided by superimposing data signals upon the power line as standard. Figure 3 shows a typical single and multimode topography for a sub-sea system.

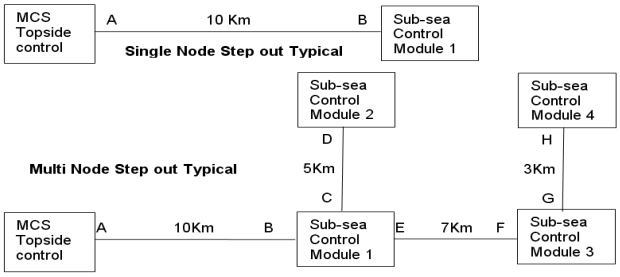
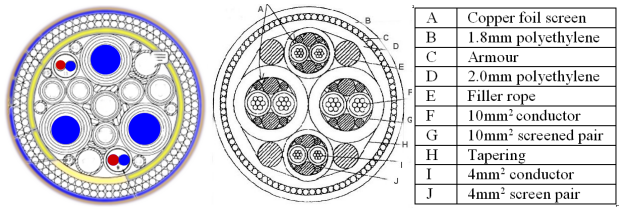


Figure 3 Single and Multi Node Step Out

5. *Umbilical*

The sub-sea umbilical is project specific; typically of up to 30Km long and costing in excess of £1m to manufacture. It is therefore of paramount importance to ensure the accuracy of the predicted communications and power attenuation early in the project decisions. A bad prediction may have cost and impose severe future system limitations. Figure 4 shows a cross section of a typical umbilical construction.



A	Copper foil screen
B	1.8mm polyethylene
C	Armour
D	2.0mm polyethylene
E	Filler rope
F	10mm² conductor
G	10mm² screened pair
H	Tapering
I	4mm² conductor
J	4mm² screen pair

Figure 4 Cross section of two different umbilical

A variable umbilical supply voltage is applied to the sub-sea system that has a relatively high operating tolerance voltage. The sub-sea Control Module (SCM) is required to operate under varying system voltages to allow for voltage drops and changing SCM load/power requirements across different sub sea system step outs.

For example, a 12Km (6mm) umbilical would typically drop 16V then a further 6Km would drop 8V thus the SCM at the first site would see 210V (assuming 226V at source) and the second site 202V. Additionally as the loads are changed (equipment within SCM turning on/off) the line voltage will be affected - wide tolerance accounts for this.

Reliable communications in the presence of consumer electronics and other sources of interference is maintained by a transceiver that uses Dual Carrier Frequency (DCF) which provides adaptive carrier and data correction, impulse noise cancellation, tone rejection, and low overhead error correction. It complies with FCC and CENELEC EN50065-1 for signalling in the 125 kHz to 140 kHz and 95 kHz to 125 kHz frequency band implementing CENELEC access protocol. Two configurable carrier frequencies at 70 or 140 kHz, utilise a

standard PLT power-line transceiver system to provide baud rate of 4800, primarily we are trying to improve this by a reasonable factor without having to make major changes to the existing model.

6. *Communication Module Specification*

The topside communication electronics module processes the command signals received from the Master Control Station (MCS) through one of the two serial gateways converting it to a Free Topology Transceiver protocol (FTT) and then via a dual channel modem to a standard PLC signal. This signal is then coupled onto the relevant sub-sea umbilical power-line channel via filter coupler cards Figure 5 The system provides a master/slave communication network, the surface computer polls the sub-sea module (read or write request) and a response from the sub-sea system confirms write action or provides data requested. The complete cycle of poll–receive is approximately 700mS, which includes the sub-sea and topside communication processing logic time.

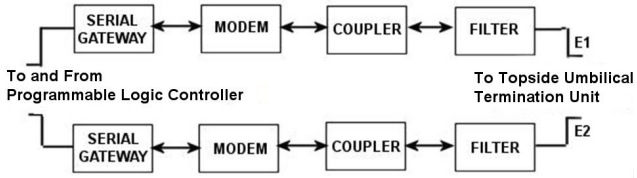


Figure 5 Well Orientation and MCS unit

7. *Modelling technique used and data comparison*

Measurements were carried out to confirm the practicality of communicating over the cable using Power-Line Carrier and to establish the attainable distance using the transceiver for the remainder of this work. The results were encouraging with an expected communication distance in excess of 25Km.
Two lengths of umbilical (3.2 Km and 9 Km) were made available, both to the same electrical specification although the longer length had an additional layer of armouring. Each umbilical contained two 4mm^2 and two 10 mm^2 pairs with an overall screen. Measurements were made on both the 4mm² and 10mm² cores for attenuation, phase velocity and impedance on the shorter cable. The longer cable was used to test a pair of prototype transceivers. A short length of cable was then cut off the 3.2Km length and used to make measurements of the electrical parameters of the cable. For characterisation of cables the measurement of the parameters (L,C,R,G) from a short length of cable is far simpler than measurements on a long length, therefore, the electrical parameters were used to calculate the attenuation, phase velocity and impedance to allow a comparison with the measured data.

A shorter length of cable of length 26.4m was cut from the 3.2Km length. This length was used to allow the total cable lengths to be calculated (from resistance measurements on the short length and complete lengths) and also allowed the electrical parameters of Capacitance (C), Inductance (L), Conductance (G) and Resistance (R) to be measured using a Wayne Kerr bridge. These parameters were measured for frequencies 100Hz to 120 KHz (above this the transmission line effects of the cable started to introduce errors into the measurements). The results of these measurements are shown in Figure 6 for 4mm^2 and 10mm^2 cables. These parameters can be used to calculate the values for the velocity ratio, characteristic impedance and attenuation.

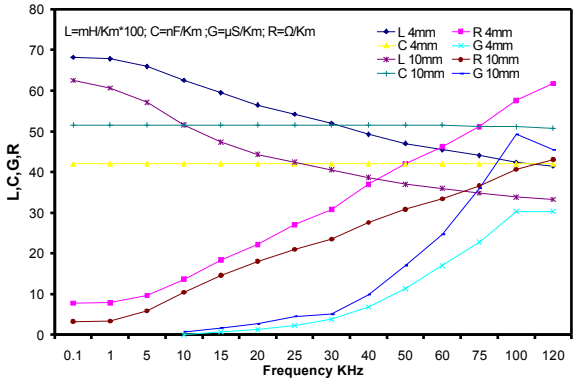


Figure 6 Measured 4mm^2 and 10mm^2 cable parameters

The results of these calculations for calculated attenuation against measured data are shown in Figure 7 and 8 for the 4mm^2 and 10mm^2 cables respectively. It can be seen that these agree in form to the measured parameters but vary a little in absolute magnitude. This error is attributed to the far from ideal experimental setup which had to be used due to the time constraints on the measurements. For example the measured resistance was typically a few hundred mΩ, a poor contact could easily add an additional hundred to this. Similarly all the other measurements are of very small values and so an offset could easily occur.

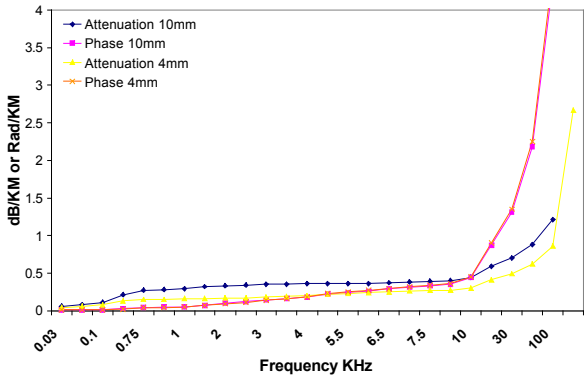


Figure 7 Measured attenuation and Phase/Frequency (4mm^2 and 10mm^2 cables)

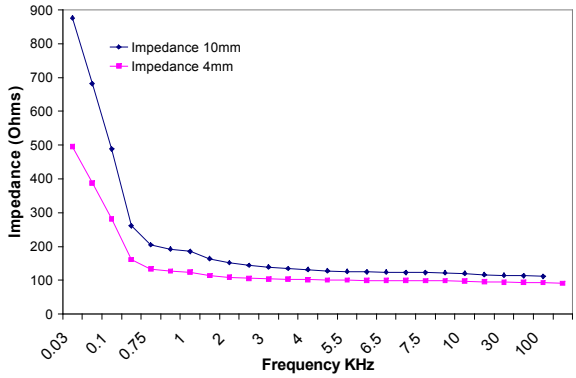


Figure 8 Measured impedance for 4mm^2 and 10mm^2 cable

Table 1 shows some cable characteristics of two conductors supplied for an umbilical electrical cable. Next step was to carryout impedance measurements.

TABLE 1 Cable characteristics supplied by the manufacturers for an umbilical

			Conductor	6mm ²				
F(Hz)	**60**	**400**	**1000**	**2000**	**5000**	**10000**	**12000**	**15000**
R Ohms	6.3	6.3	6.4	6.7	8.5	11.9	13.1	14.7
L mH/Km	0.65	0.65	0.65	0.64	0.61	0.56	0.55	0.53
C nF/Km	91	90	90	89	90	90	90	89
Z ohms	785	317	212	176	160	149	146	143
Att (dB/km)	0.05	0.11	0.15	0.18	0.24	0.35	0.39	0.45
			Conductor	10mm²				
F(Hz)	**60**	**400**	**1000**	**2000**	**5000**	**10000**	**12000**	**15000**
R Ohms	3.6	3.7	4.4	8.4	5.1	9.65	9.72	4.97
L mH/Km	0.48	0.48	0.6	0.66	-0.24	0.04	-0.05	-0.01
C nF/Km	106	105	112	137	-29	17	-3.76	0.28
Z ohms	300	122	90	81	75	70	69	68
Att (dB/km)	0.07	0.15	0.2	0.24	0.39	0.62	0.69	0.78

8. *Measured Impedance*

The impedance was measured using the 3.2Km cable length using the setup shown in Figure 9.

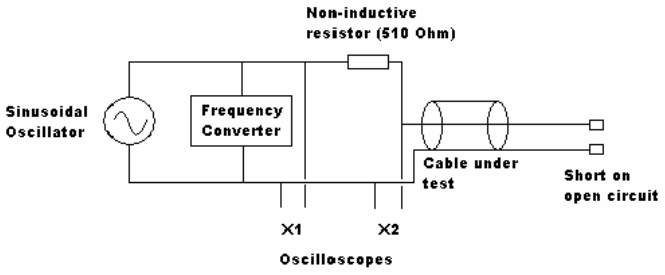


Figure 9 Setup to measure the 3.2Km cable length

Measurements of the impedance at one end of the cable were taken while the other end was either open or short circuited. The characteristic impedance was then calculated from:-

$$Z_0 = \sqrt{Z_{sc}}.Z_{oc} \qquad (1)$$

Where; Z_0 is the characteristic impedance

Z_{sc} and Z_{oc} are the short circuit and open circuit impedances respectively and plots of the measured impedance for the 4mm² and 10mm² cables are shown in Figure 10.

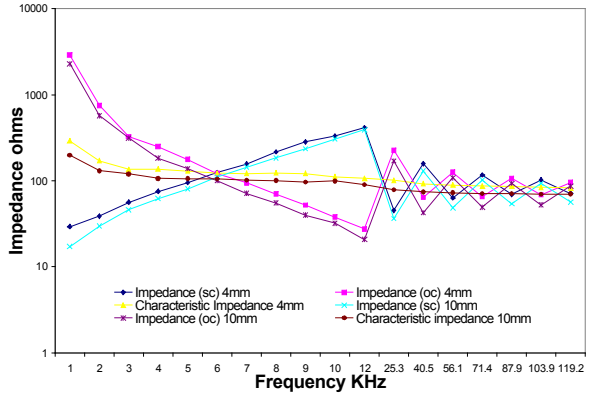


Figure 10 Measured Impedance of 4 mm² and 10mm² cable

Measurements were also made by injecting a pulse at one end and modifying the value of the terminating resistance at the far end until no reflection was seen. Plots of the reflection for different terminations ranging from 75, 110 Ω, Figure 12 shows an open circuit Time Domain Reflectometery (TDR) measurements for 4mm² and 10mm² on open circuit cable.

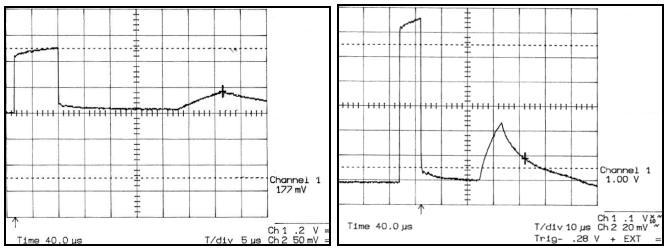


Figure11 Open circuit TDR measurements on cables

From this data the termination values of 91Ω for the 4mm² and 82Ω for the 10mm² were chosen. It is not possible to provide a perfect termination over a wide bandwidth with a single resistor due to the changing impedance with frequency. The values chosen do, however, appear to be a good compromise.

9. *Phase Delay*

The velocity of propagation can also be found from the same experimental setup as the impedance. A short or open circuited line will experience resonances whenever the length of the line is a multiple of a quarter wavelengths, therefore, by measuring the resonant frequencies on a known line length the phase velocity at resonance can be calculated. Plots of the measured velocity ratio (phase velocity/speed of light in air) are included as in Figure 12 for the 4mm² and 10mm² cables where it shows an increase in velocity with frequency as expected. Since the transceivers use 180 degree phase shift keying (PSK) dispersion should not pose any real problem, however, to get an idea of when this may become a limiting factor the phase shift introduced into the signal by dispersion should be considered.

Over a 5 kHz bandwidth (i.e. bandwidth of the transceiver) the phase delay changes by approximately to 0.1μs/Km. Assuming that the transceiver can stand a phase difference of 90 degrees, before the communication of 3.8μs takes place at 65 kHz, this then translate that transceiver can communicate a distance of 38Km which means that the system has communications limitation due to attenuation before dispersion has any effect.

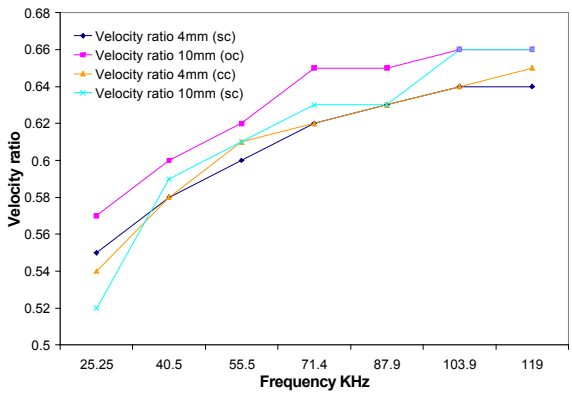


Figure 12 Measured velocity ratio of 4 mm² and 10 mm² cable

10. *Attenuation*

Similarly the cable attenuation was measured on the

3.2Km length using the circuit shown on Figure 13.

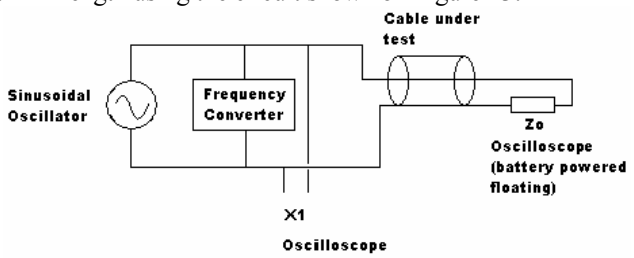


Figure13 Apparatus setup for attenuation measurement

The terminating impedance used was 91Ω for the 4mm² and 82Ω for the 10mm². The results are included in Figure 14 for the 4mm² and 10mm² cables. The calculated velocity and impedance for the 4mm² and 10mm² cables are included as Figure 15 and Figure 16. The data obtained does, however, give a very good idea of the cable parameters with errors in the region of 10% to 20%.

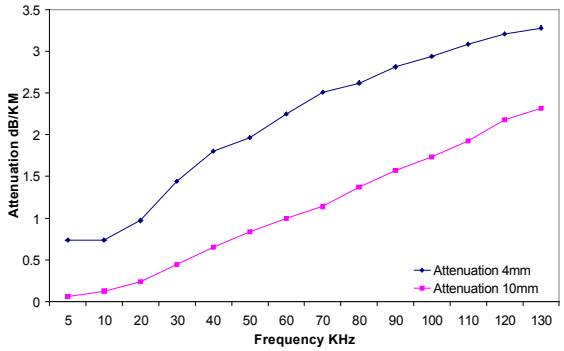


Figure 14 Measured 4 mm^2 and 10 mm^2 cable attenuation

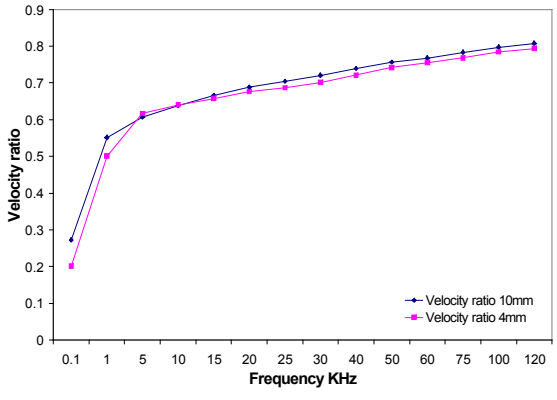


Figure 15 Calculated velocity ratio (4 mm^2 and 10 mm^2 cable)

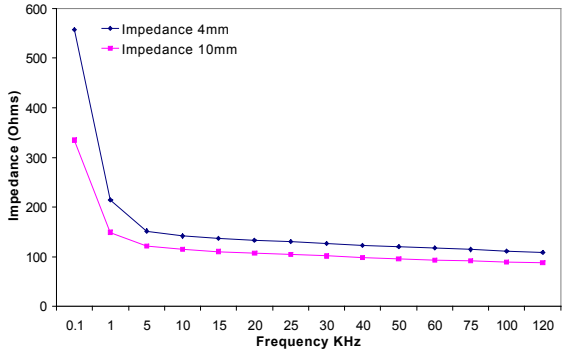


Figure 16 Calculated impedances (4 mm^2 and 10 mm^{2}cable)

11. Transceiver Tests

Two actual transceiver tests were performed, an initial prototype followed by production transceiver model. For the prototype transceiver we used two transceivers which had been modified to work at 65 KHz and were used to test the communications using the 9Km cable. The transceivers repeatedly sent messages to each other with indications of the number of messages correctly received, missed and corrupted being provided.

The transceivers worked perfectly on a single 9Km length of cable. Additional test configurations were also tested on multiple lengths with the signal going down one pair back up another and down a third. Communication was possible down two 10mm^2 lengths and one 4mm^2 length (overall 27Km) in this way with no cable terminations. When terminations were added this was reduced to two lengths (18Km). The validity of the last two tests is in doubt due to the coupling between pairs. When a pulse was injected into one terminated pair it was found that it could be detected at a level of –40dB (referenced to the input pulse) on a neighbouring un-terminated pair. This amount of crosstalk is enough to cast doubts about the use if the doubled up measurements although successful communication over a 27Km length was encouraging.

For the production transceiver an Artemis control system was used to test the umbilical. The available umbilical had been split between two reels A and B containing 4.5Km and 3.8Km lengths respectively.

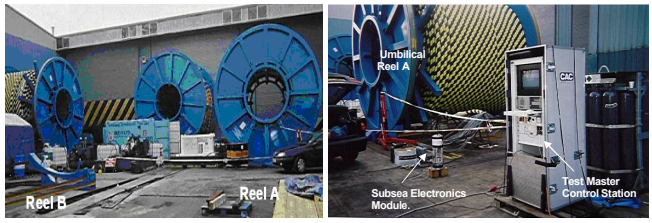


Figure17 Test two set up arrangement and typical umbilical

Both reels were linked together giving a total length of 8.3Km, for communication purposes the reels were connected together in series, thus achieving 16.6Km. This linking was repeated to achieve a total length of 33.2 Km. Due to the umbilical being on steel transport reels and not laid out across the seabed we were expecting the worse case scenario due to the coiling effects. The system was unaffected by external contamination such as power spikes, noise from welding machines used in the close proximity and thus did not need any special filtered clear power supply to function normally. To quantify the distance the loop impedence was measured at 214Ω which agreed with the calculated value of 214.4Ω as seen below**.**

4mm² 16Km long x 9.6 ohms/Km = 153.6 Ω
10mm²16Km long x 3.8 ohms/Km = 60.8 Ω

12. Findings from testing

Prototype transceiver testing has confirmed that the transceiver in its intended form (operating at 65 kHz) will be able to communicate over approximately 28Km of 10mm² cables or 24Km of 4mm² cables. However the transceivers successfully communicated over a 27Km length (18Km of 10mm² and 9Km of 4mm²). The terminating impedance required for each cable size was also identified. Better results

were confirmed by the 2nd test using the production transceiver module over 33.2Km actual which should extrapolate further.

The measured values of L, C, G and R were also different to that measured by cable suppliers. This highlights a need for collaboration with manufacturers of cables intended to be used for communication signals to compare their measurement technique(s) to aid in understanding where the differences arise.

13. Methodology for RFI Measurement

Radio Frequency Interference Emissions tests were also carried out in accordance with EN 61326: 1997 + Amendments A1: 1998 on sub-sea Control Module (SCM) and maintaining emissions levels as per CISPER 11. Input/output cables where connected, and glands were sealed and terminated with the equipment under test (EUT). The aim of the test was to simulate typical operating conditions. Therefore it was necessary to assess more than one mode of operation to maximise emissions. Prior to formal radiated emissions testing a preliminary evaluation was performed on the background to establish possible potential areas of non-conformity.

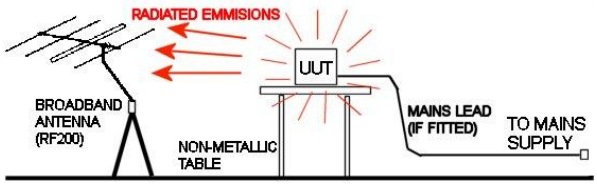


Figure 18 Emission Testing

Scans were then taken from three locations including both sides and face on, while the EUT was operating normally. The Antenna height was set to 1, 1.5 and 2 meters with the polarisation set to vertical and then horizontal polarization, The emissions from the EUT were scanned using peak measurement over a frequency range of 30MHz to 1GHz using the RF200 Broadband Antenna at a distance of 3 meters.

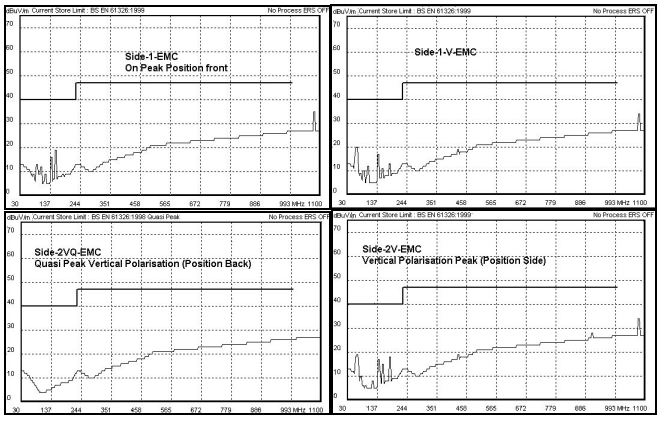


Figure 19 Show 4 different polarisations of EMC Testing

14. New Modelling Technique

Because of the risks and major investments required to evaluate and develop sub-sea networks, there is a requirement for a more precise technique to provide accurate data prediction. By producing an accurate technique for modelling a sub-sea umbilical will increase confidence of the investors to go ahead with a development. This model needs to be flexible enough to operate from low frequency to around 450 KHz in communication bandwidth of around 5 KHz in the first instance and subsequently from 1-30 MHz.

CONCLUSIONS AND FUTURE WORK

Our research to date highlighted that at high frequency bands, signals are susceptible to levels of un-intentional radiated emissions. The radiation efficiencies of such PLC networks and their radiation profiles; the potential near and far field effects and any cumulative effects of their exploitation on existing and future, high frequency, wireless services have been explored. We now wish to focus our attention to sub-sea environments and to re-use spectrum over and over again on existing metallic infrastructure in order to provide cost effective, competitive, substitute to more conventional methodologies. Our objective is to achieve a further utilisation of the high frequency spectrum outside the boundaries of the 12 mile zone. This paper has offered results obtained from some of our measurements taken at CENELEC bands and explained the present system in use by the project sponsor. Throughout the duration of our marine and sub-sea activities we will conduct experiments operating in close proximity and consider high frequency spectrum re-use in conjunction with our sponsors requirement.

RECOMMENDATION

It is worth noting that in data communication systems to bridge long distances at high data rates fibre optics are often used. Fibre Optics systems are particularly immune to electromagnetic interference and therefore very suitable for harsh industrial environments. With respect to sub-sea this technology is new and requires design and development of special water tight mate-able devices that would work in marine conditions. We could expect to gain transmit data at up to 4Mbit/s over distances up to 25Km depending on the fibre type. However the technology for long term fibre based sub-sea installations is at its infancy and carries increased loss versus target realisation.

ACKNOWLEDGEMENT†

The author is grateful for the assistance of Chris Westwell and Robert Green who have helped to compile the results.

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