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Creating global networks through an online engineering graduate program

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ABSTRACT.

Internationally the railway industry is facing a severe shortage of engineers with high level, relevant, profession and technical knowledge and abilities, in particular amongst engineers involved in the design, construction and maintenance of railway infrastructure. A unique graduate level program has been created to meet that global need via a fully online, distance education format. The development and operation of this Master of Engineering degree is proposed as a model of the process needed for the industry-relevance, flexible delivery, international networking, and professional development required for a successful graduate engineering program in the 21st century. In particular, the paper demonstrates how a mix of new and more familiar technologies are utilised through a variety of tasks to overcome the huge distances and multiple time zones that separate the participants across a growing number of countries, successfully achieving close and sustained interaction amongst the participants and railway experts.

Keywords: graduate education, online learning, networking, professional education, global reach

The need for graduate education

Two hundred years of engineering education has bequeathed a system of instruction that is steeped in strong traditions of format, delivery and style. This approach can work reasonably well with undergraduate students who are able to physically locate themselves in class rooms alongside fellow learners with whom to socialise and teachers with whom to consult.

However, practising engineers need ongoing professional development and continuing education, which places them in a different category.

- Full time work and campus-based classes are often incompatible in terms of access, timing and convenience. On-campus graduate classes are often scheduled at night to better suit the demands of employers, but usually mean that participants are absent from young families two or three nights a week for a number of years. Attrition from graduate programs is consequently much higher than from undergraduate programs (Gardner, 2009).
- However, graduate schools have been identified as critical to a nation's leadership and innovation (National Academy of Sciences, et.al., 1995), and they need to engage business, universities and policy makers, especially in the areas of science and engineering (Council of Graduate Schools, 2007). Graduate education and professional development of engineers are too important to be seen as just an extension and reapplication of undergraduate delivery and style.

Graduate engineers and the railway industry

Railways have also had a history of about 200 years. Railways were one of the major factors in driving the first half of the industrial revolution and still contribute enormously to national and global prosperity.

Nevertheless, the so-called "love affair" societies had with road-based personal and commercial transport, especially from the 1960s to the 1990s, saw railways lose market share progressively and heavily in many countries (Cantos & Campos, 2005),

so that they contracted in size and in their professional engineering workforce. As a result the industry diminished as a viable career option for university graduates, and engineers already in the industry mostly stayed with the one employer.

However, over the past 15 years there has been something of a renaissance in railways globally. Extensive privatisation of public rail authorities, together with a substantial increase in private and public investment led to railways becoming more focused on profitability and growth. Rail is also seen now as an environmentally and community friendly means of mass transportation (UIC/CER, 2008).

The steady contraction of the industry followed by its rapid expansion has left many railways with an aging professional engineering workforce and a serious skills shortage (ARA, 2009). As the many older engineers retire, the industry faces a major loss of collective intellectual capital that will take decades to regain.

An initial university driven solution

In the 1990s Engineers Australia, through its National Committee on Railway Engineering, carried out market research and identified a strong and growing need for significant, specialist courses for graduate engineers in the railway industry (Yates, 1999). These and subsequent market studies also demonstrated that such courses should be offered in a part-time distance/external mode in order to accommodate the needs of the geographically scattered engineers in the industry.

Consequently a joint venture was set up in 2000 between Queensland University of Technology and the Australian Railway Research Institute, to develop and provide two continuing professional education courses by distance education (Oghanna & Murray, 2005).

The courses were studied by hundreds of engineers between the years 2001 and 2008 and provided an important initial solution to the growing demand for professional development. The fact that the courses also attracted participation by railway engineers located in Brazil, Hong Kong, New Zealand and South Africa showed both the need for and dearth of such courses globally.

Nevertheless, despite these two courses meeting an important technical need, they did not overtly address the development of professional skills amongst participants, nor did they create and support networking between participants, both of which are critically important to engineers' careers and to the railway industry.

A comprehensive industry driven solution

In 2001 government, railway companies and universities established Australia's first national Cooperative Research Centre (CRC) in Railway Engineering and Technologies. Aside from its research activities, the CRC established a major project in which senior experienced engineers from across Australia and internationally were commissioned to prepare comprehensive content papers detailing the knowledge needed to sustain and grow the technical capabilities of railway infrastructure engineers.

A Master of Engineering (Railway Infrastructure) was established at QUT from this project, equivalent to a one year full time postgraduate qualification. The manner of

this degree's creation and operation, especially as a tool for professional development, is described in the remainder of this paper and is proposed as a suitable model for new programs that seek to offer flexible, industry-focused education of a geographically dispersed professional clientele.

Genesis of the program.

The CRC project was driven by key industry organisations and companies. Nineteen content papers were produced by specialist railway engineers, which took five years to complete, generated approximately 1500 pages of vital infrastructure knowledge and created a storehouse of raw content knowledge that would otherwise be in danger of being lost from the industry.

Traditionally, the requisite infrastructure knowledge and skills needed by a graduate engineer would be gained on-the-job while under the close mentorship of a senior, experienced railway engineer practitioner. However, this time-honoured method has been disappearing due to the increasing number of experienced engineers retiring from the workforce. So how should the knowledge preserved within those 19 content papers best be disseminated to civil engineers entering or working in the railway industry? Three alternatives were explored:

1. Publish the voluminous material in a commercial book; but sales would be limited and the books would probably just sit on the shelves of busy young engineers rather than stimulate systematic learning of the book's contents.
2. Give the material to railway CRC partner-organisations for internal training programs; but the experienced engineers who would run such programs would likely be too busy to be released for this purpose, at a time of rapid expansion within the industry.
3. Hand the material to a CRC partner-university to be developed into an accredited postgraduate award program for railway engineers.

Queensland University of Technology (QUT) was selected to develop the materials into a Master of Engineering degree, because of its many years of service to research and education in rail infrastructure. A standing committee was established with representatives from public railway authorities, private consultants and contractors, charged with the task of ensuring specificity and relevance of the learning materials to be developed from the content papers. QUT's system of academic oversight of courses is open to public and governmental scrutiny and was utilised to ensure the topics and assessment tasks have the intellectual challenge appropriate for a Master degree.

A distance-based, online learning environment steered by corporate and academic expertise as learning partners (Collis & Margaryan, 2005) was adopted as the ideal model. Civil railway engineers around the world can be located in cities and regional areas hundreds of kilometres apart from each other, and the narrow reach of on-campus classes would disenfranchise the great bulk of such practitioners.

The industry demonstrated its strong commitment to the program by providing significant initial development funding to QUT. The degree was launched in July 2008, and in 2010 has students located in Australia, Canada, Dubai, France, Malaysia, New Zealand, Taiwan and Turkey – see figure 1.

Structure and design of the program.
The format of the 19 CRC content papers varied in style, wording, layout, and structure, and so required extensive editing, formatting and desktop publishing to ensure that the key principles for workplace–oriented course design were observed while reflecting the rail context. To be relevant to railway infrastructure engineers globally, the content papers needed to be rewritten to reflect an international flavour in language, in examples and in reference to standards and practices. Through detailed consultation with the program's industry advisory committee, the topics in the 19 content papers were assembled together into a small number of coherent study texts, one for each course in the degree, as shown in figure 2.

The core curriculum planning team comprised: the program coordinator (the author of this paper with years of experience in distance education and railway research and education); an experienced industry project manager; and QUT's eLearning Services who contributed their extensive editing and learning design experience to ensure a professional, coherent and consistent structure. A great deal of effort also went into creating intuitive websites for the program, easily "digestible" structured learning modules, and interactive learning sessions. Students' appreciation of the quality of the resulting study materials is shown by the following quote:

> *From a personal perspective, the [materials] are very educational and thorough which provides a great reference guide now and in the future.*

Operation of the program.
For this distance program to reflect the needs of the corporate context, the design of the program has had to capture and share knowledge existent in the industry, support collaboration and critical thinking and build networks among the geographically widely dispersed students.

A Masters level course commits to providing challenging, achievable and authentic assessment tasks which stretch the student intellectually and professionally towards the goal of improved workplace practices. Consequently, assessment criteria were developed to ensure that industry standards are met consistently and institutional learning outcomes are measured reliably – the process is described later in this paper. By informing students of the learning outcomes being addressed through instructional text, together with consistent reference to the assessment criteria in learning activities, a transparent alignment of intended learning outcomes, learning activities and assessment is presented (Biggs 1999).

In recognition of the diverse student cohort, the program is designed to engage students with emerging technologies incrementally so that the student is attracted to the subject matter and learning intent, not the technology itself. Figure 3 shows an example of how discussion forum questions invite participation and aim to create a collegial, collaborative community. This approach also helps to overcome students' fears of using online tools, as demonstrated in the following student comment:

> *Overall very good. Initially the fully electronic interaction was daunting.*

Each person admitted to the program is required to be working in the railway industry and must obtain sponsorship from their employer, because this degree depends on participants engaging resources, information and personnel within their workplace to assist with and contribute to their learning. Almost all of the students are working full

time in a very busy industry, so the 8 hours study per week per course means most enrol in only one course per semester. It will take most of them, therefore, up to four years to complete the full Master degree, though an early exit Graduate Certificate is available for those completing four of the eight courses.

The students engage with the learning material primarily through the online learning management system, Blackboard. Each course has a Blackboard website where the study text for that course resides as a series of chapter-files in pdf format, together with discussion boards, blogs, a web-conference facility, additional resources, etc. All the study material, learning resources and assessment tasks are fully accessible to the students from the beginning of the semester so that they can pace their study to suit their schedule at work. A weekly study schedule is provided in each course to help students structure their semester and to identify the deadlines by which assessment tasks must be submitted.

Real world assessment tasks for relevancy.

All the assessment tasks in the program serve to extend the students' capabilities in research, critical thinking, analysis and synthesis, by presenting problem solving activities based on issues faced by contemporary railway infrastructure engineers. For example, the following cases form the basis of some of the courses in the degree with each case using real scenarios that are current or have happened recently. The cases are set in a wide variety of contexts, utilising different countries, jurisdictions, environments, political regimes, social expectations, and situations of national economic health.

- An intercity line with mixed traffic in South East Asia has degenerated so that users are complaining of the quality of the ride, communities are complaining of excessive rail noise, and politicians are demanding action. The students must take into account the local social, political, environmental and constrained economic contexts to prepare a major maintenance program and community consultation advice.
- Students must investigate the testing, procurement and provision of construction materials for the upgrade of a regional coal line in a tropical part of the country.
- An existing busy mixed-traffic urban line in a major Australian capital city is being considered for an increased frequency and speed of freight traffic, and the students must investigate, select, plan and describe their strategy for minimising consequent damage to the rails.
- A new 50km long light rail passenger line is to be constructed in major North American city. The students are to model the construction process, undertaking procurement of materials, preparing budgets and work plans, and dealing with a sudden changes due to unforeseen weather extremes.
- A private heavy-haul line carrying iron ore to port is located in a very remote, very hot, dry region. The students are faced with a major derailment disaster causing the death of the driver and serious disruption to the line. In this case, the information is fed to them piecemeal as happens in reality, and models a pre-mortem approach to anticipate a real derailment (Klein 2007).

Much of the information the students need for these tasks is provided in the study text in each course, with additional information readily available via the internet and commercial literature databases to which QUT subscribes on behalf of its students. Vital information not available otherwise is either generously provided by industry

partners or can be sourced from a student's workplace. In this way the assessment tasks are relevant and resourced, and informed by the student's local situation.

Because of the need for assessment to be as authentic as possible in this professionally focused program, almost all of the assessment tasks across the eight courses are built around progressive development of the case studies described above. Students are required to present their work on a given case study via three assessment tasks due generally around the 5th, 9th and 15th weeks of the semester. A submission might be a written report, a spreadsheet analysis, a set of hand calculations, a construction plan, an individual or group verbal presentation, a round-table discussion, contributions to a blog discussion, self assessment or peer assessment. There are no traditional formal written examinations in any course in the program.

Each assessment task is graded according to a Criterion Referenced Assessment (CRA) sheet, which is a table of criteria appropriate to that task together with a set of standards describing what the student's submission must demonstrate in order for it to be awarded a given grade against each criterion – see figure 4. A student's grades from all the tasks in a given course are then combined to determine the student's final overall grade in that course.

A focus on interaction.

A graduate program brings together people with advanced levels of technical knowledge and professional skills. This is especially so amongst the experts who prepared the study materials and/or who provide leadership for the QUT program and/or who are closely involved in providing tuition in the courses. But it is also true amongst most of the engineers who enrol in the program. The engineers studying this degree vary from fresh graduates who have been working in the railway industry for only a year or so, through to others who are long-standing graduates with 20 or more years of railway experience in three or four countries around the world. The many different states and nations they are working in while studying this degree have different standards, practices, terminologies and legislative frameworks, let alone the different community and national contexts mentioned before. This situation provides a potentially very rich internationally relevant learning environment.

The study materials in each course provide a sound base for building the technical knowledge these engineers seek, but a Master degree requires much more than simply learning extra facts and numbers. There is a wealth of knowledge, experience and skill amongst the students and the expert engineer tutors that is far greater than that contained in the course materials and must be tapped and shared to enrich the students' learning.

In each course in the program, course leaders strive to cultivate familiarity and even friendships amongst the students even though students and experts are separated by huge distances and by multiple time zones. As a cohort of students passes through the program, they are observed to become more trusting of each other and more prepared to speak of personal experiences, to debate issues vigorously with each other and with the expert tutors, and to assist each other to improve their learning and come to grips with sometimes vexed questions that the greater engineering fraternity is grappling with. Techniques utilised in the program promote this interaction with each other and the tuition experts and include the following:

- multiple tele- and web-conferences occur in every course in the degree;
- discussion forums are created by tuition experts or by the students themselves, in which students propose topics or seek information or understanding from the group;
- whole-of-cohort group email facilities keep them all in touch and interacting with each other and the tutors;
- blog assessment tasks that construct broad enriching discussions centred on a provocative question, and in which all the students must progressively contribute to and comment on others' contributions - the blogs assess students' critical and analytical thinking, and promote interactive learning and sharing of workplace issues;
- team projects and presentations, in which small virtual teams of 3 students per team are constructed with people from different organisation and locations – this ensures equity in that members in each team must communicate and interact using virtual means;
- shared documents and work tasks using technology such as Google Docs;
- small symposia conducted via various forms of technology in which virtual groups comprised of 5 geographically separated students conduct an online live discussion/debate over a current issue, and assesses each others' contributions after first developing the criteria by which they will carry out this assessment.

As each student cohort progresses through the Master degree program they encounter a different mix of these interactive tasks in each course, with progressively more difficult challenges as students become more familiar with their cohort. For example, in their first course they work through a weekly discussion forum of challenging topics and a blog assessment task. In their third course they do online presentations in virtual teams, in their fourth course they conduct group debates in which they assess each other's skills. Each interactive opportunity has been designed to steadily expand and deepen these global networks of students and experts, most of whom may never actually meet each other face-to-face.

Does it work?

The program's worth can be measured by the expressed opinions of both industry leaders and student participants. Each semester all 40,000 students at QUT are asked to complete an anonymous, online survey of all the courses they are studying, in which they rate and comment on the subject's content, operation and teaching. In the two years since the railway degree commenced, the courses and teaching in this Master degree have been rated by its students at a mean score of 4.3 out of a maximum 5, with scores for individual courses up to 4.8 out of 5. Typical comments from students in the degree are:

> *The interactive aspect with other participants was great.*
> *I thoroughly enjoyed the blog activity in assignment 2. I was a bit unsure of this activity leading up to it but learnt a lot from the postings of the other students.*
> *The virtual team project was good because it made us think outside the square and challenged our collaboration ability.*
> *Phone hookups were valuable.*
> *It has been a very motivating and enjoyable studying experience being involved with people who are considered top in their rail related professions. Their real-life experiences has (sic) provided a great insight into the railway industry.*

The course is unique and is an excellent means of learning about the railway industry quickly.

Overall, very enjoyable and I look forward to Semester 1 next year.

Valuable comments are also made each semester by students concerned with specific aspects of a given course, and are useful in improving future delivery of each course.

More interaction between colleagues in general discussion in this course, not just during assessment time.

The video clips this semester needed to follow a more structured outline.

The marking of some assignments in UDN502 seems inconsistent and the rules are not clearly defined.

The industry advisory committee that guides the development and operation of the Master degree is comprised of senior, experienced engineers who are very sensitive to the growing need of the industry for professional and technical development of its engineering workforce. Some of the comments arising from that committee are:

The masters program has extensive academic rigour, with a lot of fundamental railway teaching and a substantial dissertation.

Students undertaking this program would automatically be eligible for substantial credit towards continuing education requirements of their professional body.

This course is truly unique and provides a firm basis for this industry going forward.

Because this is a distance-based program and many students are dispersed across the globe, feelings of isolation and disconnectedness could be expected to lead to a high rate of attrition of students. Consequently the many opportunities for interaction described earlier were created to promote networking and collaborative learning and minimise the sense of separation. This approach seems to have worked. Of the 50 people who have commenced studying this degree over the past two years, 45 are continuing in the program, 4 have withdrawn, and one is on leave of absence. Of the 45 continuing, five have graduated with the Graduate Certificate but have also decided to continue their studies to obtain the full Master degree. The first Master degree graduates are expected at the end of 2011.

Conclusions

As Bonk (1999) observed, web-based learning offers a chance for students to enter into dialogues about authentic problems, collaborate with peers, negotiate meaning, become apprenticed into their field of study, enter a community of experts and peers and generally be assisted in the learning process. In this online, internationally subscribed Master degree that is unique to the railway industry globally, the teacher becomes a facilitator of and aid to the learning process, through resources that enable rapid communication and collaborative learning in ways not possible until relatively recent times.

The program is built on a collaborative framework that began with its genesis in experts working with universities to capture their soon-to-be-lost knowledge, progressed through the development of that knowledge into a full graduate program, and climaxed with a structure of learning that brings together students, experts and academics internationally in an online, real time format.

Consequently, students as they progress through this professional level program take back to their workplace not only increased and highly relevant technical knowledge, but also a world-wide network of experts and peers, together with experience in sourcing, sorting and processing complex information about typical challenges faced in the railway industry. The students are developing capabilities of collaborative problem solving, critical thinking, communication via various media, and high level research skills. They are greatly improving their skills in managing and progressing their learning in this rapidly changing field.

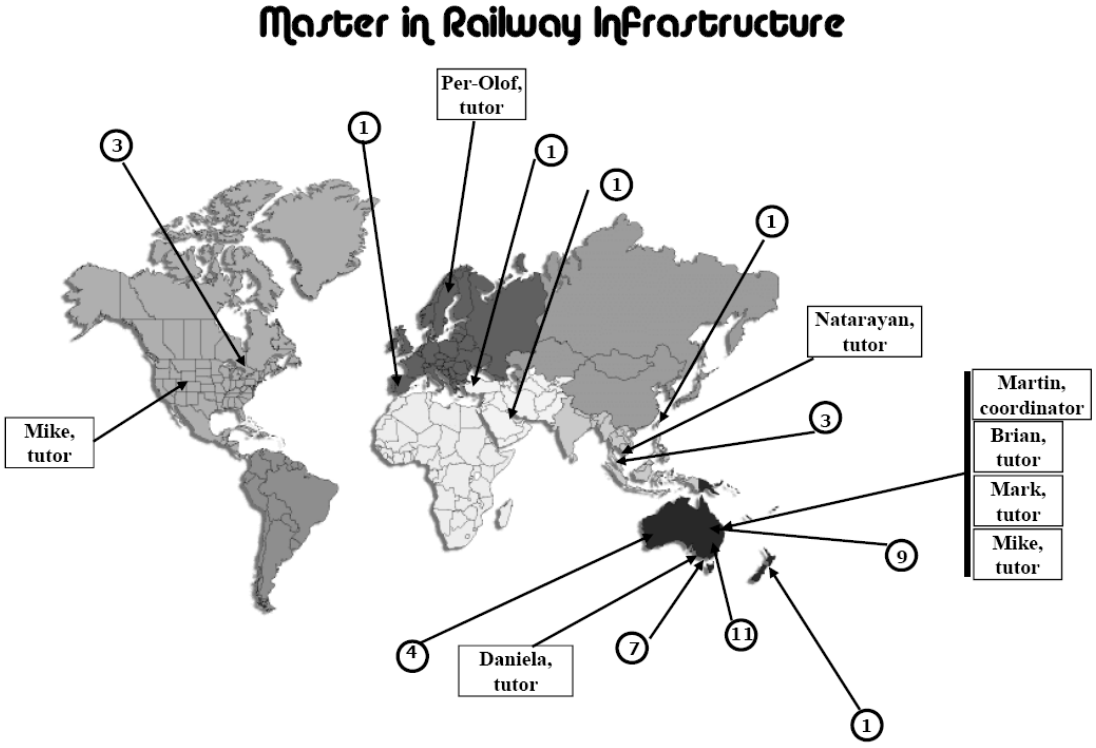

Figure 1. Map of students' and experts' numbers at each location.

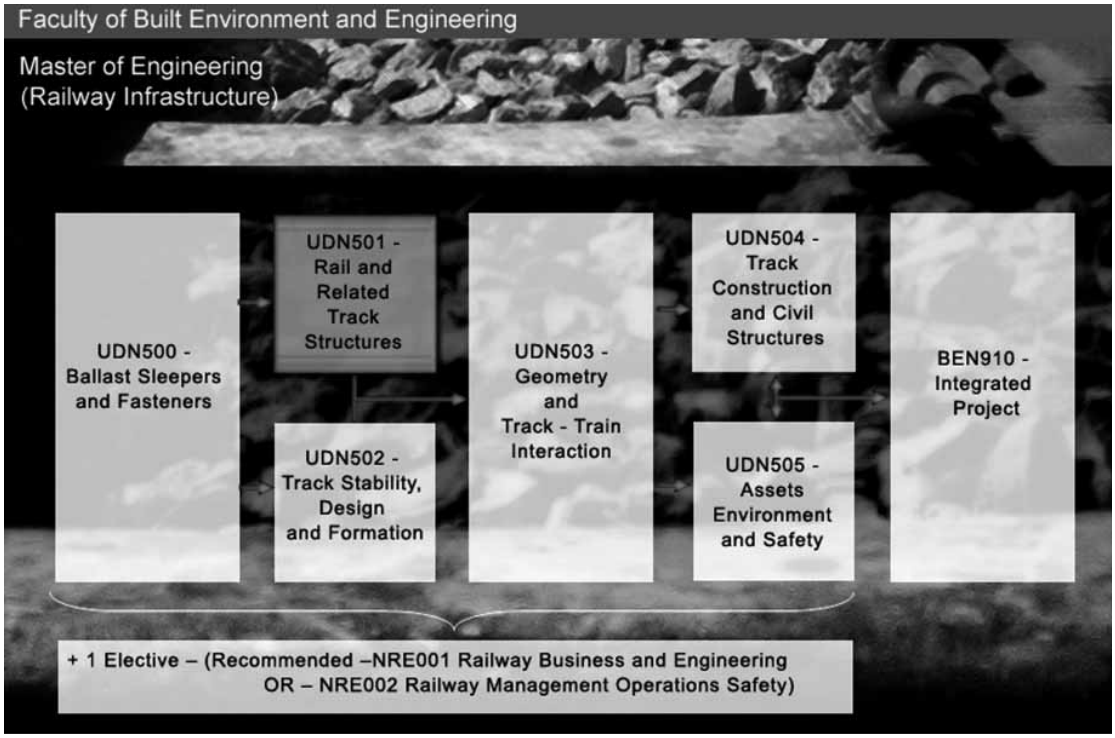

Figure 2. Screen shot from one of the program's Blackboard websites showing program structure.

Display Order	Forum	Total Posts	Unread Posts
1	UDN501 - Week 1 Introduce Yourself to your colleagues	27	27

1. Who are you? Tell the rest of the group a bit about yourself!
2. Who do you work for?
3. What sort of projects are you working on?
4. Why did you choose to do this course?
5. What are your expectations of this course?
6. And, only if you wish to do so, post a phone number and/or email address.

Posting to a Discussion Board

1. Click on the 'Introduce yourself' title above
2. Click the 'Thread' button (a thread is begun as a single post, which then can be replied to, and the reply is replied to, and so on.)
3. The 'Add thread' form will appear
4. Enter a subject for the thread, like the subject of an email message
5. Enter text into the message field
6. To add the post to the forum, click 'submit'.
7. To create a new topic or conversation thread, click on the '+ Forum' button above.
8. Post to a new topic in the same way.

Figure 3. Example of formative open ended questions posed to generate sharing of issues in discussion board.

UDN503 TRACK GEOMETRY AND TRAIN INTERACTION, ASSESSMENT 2
CRITERION REFERENCED ASSESSMENT SHEET.

Criteria	7	6	5	4	2
Argue the influences of track characteristics and vehicle parameters on the safe operation of trains.	With regards to • comprehension and discussion of the nature, relevance and quality of the many and varied sources of track condition information and of the issues involved with track condition, • interpretation of that information and understanding of its implications for safe and efficient operation of trains, and the consequent establishment of sound and defensible maintenance intervention thresholds, the report demonstrates:				
	high level reasoning and a very professional approach.	sound, competent reasoning, professional approach	sound reasoning and a professional approach.	adequately sound reasoning.	poor logic, erratic or absent understanding.
	All requirements for this assessment task have been met fully. Excellent and outstanding report presentation, no grammatical or spelling errors, professionally set out & structured & referenced, highest quality English and graphs and figures, all analyses professionally presented and very easily followed, word count < limit.	All requirements for this assessment task have been met except for one minor one. A minor loss of neatness in text or setting out or graphics or referencing, very good English, at most 1 error in spelling and grammar per page, all analyses well presented and easily followed, word count <limit.	The full maintenance plan and all but one key requirement for this assessment task have been met. Generally neat in setting out and graphics, good English, some errors in referencing, at most 1 error in spelling or grammar per page, most analyses well presented and easily followed, word count < limit.	The maintenance plan and at least half of the other key requirements for this assessment task have been met. Acceptable neatness in setting out and quality of English, widespread but minor errors in referencing, no more than 2 errors in spelling or grammar per page, figures and graphs adequate, word count just beyond set limits.	The plan is missing or clearly in significant error, less than half the key requirements meet. Low quality presentation and layout, many errors in spelling or grammar throughout the report, generally poor use of English, significant errors in referencing, word count well beyond set limits
Critically analyse & solve problems related to train-track interaction in diverse ethnic & organisational contexts.	The maintenance plan is very comprehensive in the factors considered and in the activities presented, is very sound in its engineering, rational and logical in the relationship between its components, is based on careful and accurate analyses of data.	The maintenance plan is comprehensive in the factors considered and in the activities presented, is sound in its engineering, rational and logical in the relationship between its components, is based on careful analyses of data with one minor flaw.	The maintenance plan has reasonable scope in the factors considered and in the activities presented, is mostly logical in the relationship between its components, is based on adequate analyses of data with a couple of minor flaws.	The maintenance plan is barely adequate in the range of factors considered and in the activities presented, has some logic in the relationship between its components, is based on analyses of data that has at most one serious flaw.	The maintenance plan is inadequate, does not consider some significant factors, important maintenance activities are missing, poor logic in the plan, based on seriously flawed analyses.
	With regards to consideration of and allowance for the social, political and cultural issues impacting on the project and plan, the report demonstrates:				
	a comprehensive, wide ranging and excellently supported approach.	a wide ranging and well supported approach.	a sound approach covering all the major issues.	some consideration and discussion of the major issues.	little or no consideration, or poor comprehension.

Figure 4. Example of CRA (criterion referenced assessment) sheet.

Biography.

Martin Murray graduated with a BE(Civil) and later a PhD from the University of Melbourne in 1978. He's been an engineering faculty member of the Queensland University of Technology for the past 18 years and has published over 120 papers, especially in the field of railway infrastructure engineering. In 2008 he received the Railway Technical Society of Australasia's prestigious biennial individual award for 20 years of service to the railway industry, and in 2009 the National Teaching Excellence Award from the Australian federal government..

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