

Railway Knowledge – a fundamental for regulation of railway safety

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SUMMARY

The structure of the railway sector in Europe has changed as a result of the legal imperative to separate train operations from infrastructure management. The vertically integrated railway that, in previous times, provided an environment in which a broad knowledge of the railway system could be developed, no longer exists. This change has brought about unexpected challenges, in particular the erosion of comprehensive railway knowledge.

Additional boundaries created by vertical separation of railway activities have also placed a greater emphasis on the need for independent safety regulation. To function effectively, safety authorities also require sufficient staff possessing a comprehensive knowledge of the railway system as a whole.

This paper describes the problems that faced the RSC in 2010, with particular reference to the skills shortage that existed at that time. It explains how these problems have been addressed through the implementation of a graduate development programme in conjunction with Engineers Ireland. In the second part of the paper, one of the graduate engineers on the RSC programme explains how his knowledge and skills have developed through a combination of practical experience and further studies. The paper concludes with an outline of how the programme is adding value to RSC activities.

INTRODUCTION

Significant changes have taken place in the institutional structure of the railway sector in Europe as a result of the imperative to provide market access by separating train operations from infrastructure management, as mandated by European legislation. Furthermore, ownership, maintenance and overhaul of railway vehicles may no longer be an integral part of a train operating company's corporate activity; and the design and manufacture of locomotives, passenger coaches, and freight wagons is now in the hands of specialist suppliers. Track maintenance activities and the renewal of structures and signalling, communications and train control systems is more often than not contracted out by infrastructure management companies.

Not only does this fragmentation of the sector present a challenge to the preservation of railway knowledge, but it also creates a greater need for development and retention of such knowledge if railway safety is to be assured and continuously improved. The consequences of a loss of corporate knowledge are well understood in Ireland; this was determined to be a significant contributory factor to the collapse of the Malahide Viaduct on the Iarnród Éireann (Irish Rail) network in August 2009.

The vertically integrated railway which previously provided a learning environment wherein individuals could gain knowledge about all aspects of railways, from concept to operation, no longer exists. Interfaces between technical systems, operating and maintenance procedures, and the people that are responsible for making a railway operate safely are now separated by corporate as well as technical boundaries. Ensuring railway safety in this changed environment demands a robust structured approach to the management of railway knowledge.

Railways are complex socio-technical systems with multiple interfaces. It is simply not sufficient to understand the technicalities and operating requirements of one aspect of a railway without an adequate comprehension of the effects of that particular aspect on the railway system as a whole and the effects of other aspects of the railway system on it. Not only is this knowledge of the railway system a necessity for each of the key sector players, but it is also a fundamental requirement for a National Safety Authority (NSA) which carries responsibility for assuring safety through supervision of railway undertakings and infrastructure managers.

There is no great difference in the range of tasks that a large or small NSA is required to undertake. However, in countries where there are only small railway sectors NSAs have to deliver these tasks with a proportionately sized organisation. In such cases there is a requirement for individuals with a broad knowledge of railway engineering systems and operational practices. This paper explains how the Railway Safety Commission (the NSA for the Republic of Ireland) has met the challenge to develop a new generation of professional railway experts.

THE PROBLEM – A REQUIREMENT FOR RAILWAY-SPECIFIC KNOWLEDGE

In relation to the railway sector in Ireland the Railway Safety Commission (RSC) is a young organisation. It is a non-commercial statutory body that was established on 1st January 2006 in accordance with the requirements of the Railway Safety Act, 2005.

Recruitment commenced immediately, with the objective of establishing a cadre of experts capable of carrying out the safety supervision functions mandated by European and national legislation, but this did not turn out to be an easy task. By September 2010 only 70% of the technical positions had been filled, and the range of expertise available was heavily skewed towards the civil engineering aspects of railway infrastructure.

In late 2010 a comprehensive review of human resources required by the RSC (in terms of technical competence and numbers) was undertaken. This revealed significant gaps in the professional skills available within the RSC team in the railway engineering and operating disciplines. The six appointed Inspectors comprised two chartered civil engineers, two mechanical engineers (both have since attained C.Eng. status), and two others who did not hold professional engineering qualifications. Apart from the Commissioner, there was a noticeable absence in-house of professional experience in rolling stock, electric traction, railway signalling, and train operating practice.

At that time the full impact of the economic crisis of 2008 was being felt, and by early 2011 Ireland was committed to an ECB / IMF / European Commission bailout programme to restore the fiscal balance. A moratorium on staff recruitment and the imposition of a strict employment control framework across all government departments and public sector bodies ensued. Staff establishment for the RSC was progressively reduced from 12 to 8 full time positions. Not only could existing vacancies not be filled, but two Inspectors who resigned could also not be replaced. This resulted in an ever increasing dependence on external consultancy services for the execution of routine tasks.

THE SOLUTION – RAILWAY-SPECIFIC TRAINING AND EXPERIENCE

The RSC review concluded that, in order to provide for long-term sustainability and to maintain functionality in the immediate circumstances, the solution lay in 'growing its own timber' — a graduate training scheme operating in the organisation could facilitate development of the expertise in railway engineering and operations necessary to equip graduate engineers with the level of competence required to become railway safety inspectors.

This approach was further explored with Engineers Ireland (the professional body for engineering in Ireland), and culminated in the design of a bespoke graduate development programme that would enable a graduate engineer to achieve Chartered Engineer (CEng) status within four years. The programme was specifically focussed on developing railway-specific knowledge and expertise and it embodied a combination of practical experience and further academic learning.

In order to comply with the aforementioned employment controls, it was proposed that Engineers Ireland would employ the graduate engineers and that they would be seconded to the RSC for the duration of the four-year training period. Having received 'no objection' to the proposal, the RSC proceeded to make arrangements with Engineers Ireland to conduct a call for candidates.

Experience had demonstrated that one important aspect of bringing people into a small organisation, like the RSC, was the need to ensure a good 'cultural fit'. To that end the process for recruiting the graduate engineers was carefully designed and comprised the following steps:

- (i) The call for candidates for two positions was confined to recently graduated engineers. It was based on job criteria provided by the RSC and conducted by Engineers Ireland;
- (ii) Initial screening by Engineers Ireland of applications provided the RSC with a short list of 20 candidates (plus 10 supplemental candidates) for review;
- (iii) Commissioner and Head of Administration of the RSC conducted separate reviews of the candidates CVs, each preparing a list of suitable candidates, which were compared for preparation of an agreed list of 8 candidates for interview (the separate lists already agreed on 6 candidates);
- (iv) Interviews were held at Engineers Ireland and chaired by their representative with the Commissioner and Head of Administration of the RSC also on the interview panel — this process resulted in four candidates being selected for second round interview;
- (v) The second round was less formal and comprised a group visit by the four shortlisted candidates to the RSC offices to 'meet the team' and provided an opportunity for them to see the work environment and talk with each of the function managers; and
- (vi) All second round interviewees were requested to confirm their continued interest in the positions (all four did!), and the RSC management team met to select two of the candidates.

A contract was entered into with Engineers Ireland whereby the two selected graduate engineers commenced their placement with the RSC in September 2011. By that time two of the appointed Inspectors had resigned, but it was decided to gain some experience of running the programme before taking any further steps. As it turned out the programme was a success from the start, and this gave the RSC the confidence to build on the scheme.

In an effort to overcome the skills deficiency resulting from the two resignations, and to further provide for the longer-term resolution of this critical issue of technical resources, the RSC entered into a second agreement with Engineers Ireland in June 2012. In this case two graduate engineers with 3-4 years' railway experience were placed with the RSC on a two-year conversion programme. They subsequently became warranted railway safety inspectors, and both achieved CEng status during the first half of 2014.

Two more recent graduates in engineering were placed with the RSC from January 2013, also on the four-year training programme under a further agreement with Engineers Ireland. Whereas the six graduates that have been placed with the RSC nominally fill the head count required they are not yet fully up to speed, and the RSC has no option other than the continued engagement of some external expertise for support in specific technical areas such as railway rolling-stock and signalling. However, as the graduates in training have grown in knowledge and experience, the benefits have rapidly become apparent and dependence on external consultants has already declined considerably.

The objective of the graduate development programme is to ensure that adequate railway-specific knowledge and skills are available within the RSC to meet its business needs by the end of 2015. In the second part of this paper one of the first two graduate engineers to join the RSC programme explains how his knowledge and skills have been developed through a combination of practical experience and further studies.

THE EXPERIENCE – THREE YEARS OF RAILWAY-SPECIFIC TRAINING

My railway career commenced in September 2011 when I joined the RSC graduate development programme with one other graduate engineer. We were the first two to start this programme which has since grown to a total of six graduates. When I started I had only just completed my engineering degree and had no railway experience at all.

The first task that the two of us were given was to study *Red for Danger* – L.T.C. Rolt's classic on the history of railway accidents and the evolution of railway safety in Britain and Ireland. However, there was a significant purpose to this task; I was required to give a talk on the interlocking of points and signals at the next 'RSC team day' which was just five weeks away.

This was one of several tasks and visits that occupied the first three months of our training. An important activity for us was meeting key people in the various railway organisations within our remit, and we also received basic training inductions from the RSC managers in their respective areas of responsibility. At that stage of our training

we looked at all aspects of railways; from the components that make up the infrastructure, the methods of operation, the key functions and equipment of rolling stock, and inspection of assets, to the legislative framework that governs the railway sector. We also studied the Irish railway network and started mapping the basic features.

Building on knowledge gained from *Red for Danger*, emphasis was placed on understanding how railway rules and regulations were developed as a result of learning from accidents. Training also consisted of formal courses such as Personal Track Safety (PTS) and Safe Pass training, both of which are required to access the live railway track in Ireland. In addition, we attended a Railway Experience Course which was held on the Romney Hythe & Dymchurch Railway, a 15-inch gauge fully functional passenger railway in the South East of England – the world's smallest public railway. This course consisted of formal training in a safer environment compared to that of the 'full-size' main line. It also enabled us to network with other railway people outside of Ireland. As an addendum to the course we visited the mechanical signal box at Tenterden on the Kent & East Sussex heritage railway, which gave me the opportunity to examine a signalling locking frame for the first time.

Continuing development

Following on from the initial densely packed period of training we started to transition towards doing small jobs and participating in inspections accompanied by qualified Inspectors. This was still very much 'on the job learning' which allowed us to be useful while having little responsibility placed on us. Through this continued training and accumulation of experience the programme enabled each of us to move from a situation where almost 100% of our time was spent in formal training, with little responsibility at the start, toward increasing levels of work activity and responsibility with lesser time required on courses. The method of training adopted was to:

- First, study and observe tasks undertaken by Inspectors;
- then undertake the activity as a support to an Inspector;
- progression to leading tasks under supervision of an Inspector, and
- finally, leading tasks of increasing responsibility on our own.

Continuous support was provided by RSC Inspectors, and some of the activities required further formal training at different points along the learning curve. Much training was undertaken, both internally and externally, with some courses being one day and others being a week or more. Not all of this training could be listed here, but some of the core external training courses undertaken and not mentioned elsewhere were:

- Occupational Health & Safety Management Systems (OH&SMS) Auditor/Lead Auditor based on OHSAS 18001:2007 (certification required in order to lead audits on SMS compliance)
- Institute Of Mechanical Engineers – Traction and Rolling Stock course:
 - Introduction to Rolling Stock
 - Traction & Braking
 - Vehicle Dynamics and Vehicle-Track interaction
 - Fleet Maintenance
 - Vehicle Acceptance and Approvals
- Level 5 Occupational First Aid
- Legislative framework - Investigation and Enforcement provisions (La Touche Training, Dublin)
- Risk Assessment training (provided by Risktec Solutions, UK)
- Human Factors course (delivered by Dr Claire Dickinson, ORR)
- ISO Standards Training (9001; 17020; and 19001)

In addition to the above, a number of conferences and seminars were attended. Some of these were for learning purposes and others additionally fulfilled the RSCs obligation to attend. As a safety authority, the RSC needs to be represented at certain railway sector meetings for the sharing of industry information and also to represent any specific needs of the Irish railway sector in regard to the development of European legislation. In this context we have attended many such meetings and events, at first together with relevant superiors, but later, as we grew in experience, without the need to be accompanied. For myself, such events have included the following:

- Signalling & Train Control Conference – Zurich, March 2012
- IMechE Seminar “Axles, Bearings & Wheelsets” – London, May 2012
- Innotrans – Berlin, September 2013
- IRSE Technical Meeting “Clapham 25 Years On” – London, December 2013

Further academic learning

In September 2012 the first four graduates appointed to the RSC programme commenced the MSc programme in Railway Systems Engineering and Integration at the University of Birmingham. This is understood to be one of a very limited number of railway specific masters programmes of this type in the world with the others being run in Australia. The programme teaches all aspects of the railway system and explains the interaction and dependence between the various sub-systems. The full programme comprises eight modules, as follows:

- LMR31: Strategic Management of Railway Operations,
- LMR32: Railway Rolling Stock Systems Design
- LMR33: Railway Traction Systems Design
- LMR34: Systems Engineering and Integration for Dependability
- LMR35: Railway Infrastructure and Track Systems
- LMR36: Railway Control Systems Engineering
- LMR37: Railway Economics and Technology Management
- LMR38: Ergonomics and Human Factors for Railways

The MSc can be taken full-time over one year or part time over several years. Due to our busy work schedule it was agreed between the RSC and the University of Birmingham that in our case it would be spread over three years. To date, I have successfully completed three modules in each of the first two years and I plan to complete the programme in 2015 with the final two modules plus a dissertation on circumstances giving rise to short life of mainline locomotives wheels.

For me, the MSc programme is providing a rounded high level overview of railway systems with suitable detail supplied where required. One great advantage is that there are many people on the course from different backgrounds and disciplines, ranging from new graduates who had never worked on railways to technicians and engineers with many years' experience. The course has provided me with an opportunity to network with many railway professionals, both academics and experienced professionals, as well as upcoming railway engineers.

Professional engineering development

One of the goals of the graduate development programme is the achievement of CEng status. The path to this designation is by gaining the level of knowledge and experience required to hold the position of a responsible professional engineer. As part of our development all RSC Inspectors are encouraged to join one or more relevant professional engineering institutions in order to facilitate professional development, networking and industry contact.

As we gained knowledge and experience we diverged into different areas of speciality with the aim being for each graduate to have a primary and secondary area of expertise, and together to cover all railway disciplines. In doing this we developed an in-house capability to support all work activities of the RSC and, at the same time, we are contributing to a reduction in the organisation's dependence on external services. My particular areas of interest for specialist development are rolling stock and signalling. However, such specialisation does not mean that we do not have an appreciation and experience in other areas, and we are all capable of supporting other activities. In support of my selected areas of specialisation the professional engineering institutions that I have joined are:

- Engineers Ireland (I have been a member since I was in university)
- Institution of Mechanical Engineers (IMechE)
- Institution of Railway Signal Engineers (IRSE)

The minimum requirements for chartered membership of each institution are slightly different. Because of the specialist nature of railway signalling, the IRSE require candidates to demonstrate their knowledge by passing at least four of the IRSE exam papers. I have opted to study the following four modules:

- Module 1: Safety of Railway Signalling and Communications (mandatory module)
- Module 2: Signalling the layout
- Module 3: Signalling principles
- Module 7: Systems, Management & Engineering

I am currently working through these modules together with one of my fellow graduate engineers. I successfully completed Module 1 and Module 2 in 2013 and am scheduled to sit the exams in 2014 for the other two modules. To achieve this result, the RSC built study time into the work schedule, and support was provided in the form of internal training from a retired signal engineer supplemented with training by Risktec Solutions in the UK. This area of learning has already delivered benefits for RSC work activities, both in relation to review of signalling project documentation in connection with the process for authorisation to place in service and in conducting audits of compliance with SMS requirements.

Table 1 – Membership of professional bodies

	Institution of Engineers of Ireland	Institution of Civil Engineers	Institution of Mechanical Engineers	Institution of Engineering & Technology	Institution of Railway Signal Engineers	Permanent Way Institution	Institution of Railway Operators	Institution of Occupational Safety & Health	Institute of Logistics & Transport
Com	•		•		•	•			
PI-1	•								•
PI-2	•							•	
PI-3	○	•				○			
I-1	•	•				•	•		
I-2	•		•		•				
I-3	•		•	○			•		
I-4	•	○				•	•		
I-5	•	○				•	•		
I-6	•			○	•				

• Current members

○ Prospective members

Progression to responsible activities

As stated previously, graduates gradually took on more responsibility as training and experience accumulated; starting from a position where we observed and then moving towards managing our own projects. We worked along the same path at first and then gradually diverged into our own areas of expertise. In March 2013, a year and a half after starting the programme, I was warranted as an Inspector under the Railway Safety Act 2005 which granted me the powers of an Inspector of the RSC under the Act. The principal work areas with which I have been involved include the following:

- Audits
 - The Management of Wheelset Maintenance & Overhaul (2012)
 - Review of Heritage Railway Safety Management (eight railways audited 2012)
 - Maintenance and Operation of the Iarnród Éireann Traffic Control and Signalling System (2014)
 - The Management of LUAS Tram Maintenance (2014)
- Authorisation to Place in Service – one heritage steam locomotive (2013)
- Assessment and Certification
 - Safety Certification of five heritage railways based on assessment of their respective SMS (2013-14)
 - Certification of Iarnród Éireann (Irish Rail) as Entity in Charge of Maintenance (ECM) for freight wagons in accordance with Commission Regulation (EU) No. 445/2011 (2012 – 2014)
- Attending European Railway Agency (ERA) meetings in Lille / Valenciennes
- Industry follow-up on particular safety issues
 - In-service failure of mainline locomotive axle journal bearing
 - Abnormal wear of diesel-mechanical railcar axle journal bearings
 - Investigation into problems with tram axles
- Inspections
 - Bridges; Stations; Level Crossings; Rolling Stock; Heritage Railways; Track Walks; Cab-rides; etc.
- On Call duties
 - Incident reporting; Incident follow up; Post Incident Inspection (PII)

The audit process forms a large part of the supervision activities undertaken by the RSC. It is also required for surveillance of ECMs (mentioned later) but using different criteria. After training on the job through participation in audits, and external training as an auditor to OHSAS 18001:2007, I was able to become involved, firstly as a second auditor, and later leading audits within my specialist areas. The audit on the management of wheelsets allowed me to use the knowledge I had gained and also taught me a lot, not only about various types of wheelsets, but also about the methods used to maintain railway rolling stock.

In 2012 the RSC engaged consultants to lead an audit of the eight self-contained heritage railways in Ireland. I was chosen to co-ordinate this audit and I followed it through from initiation to conclusion; attending all the on-site visits and reviewing and commenting on the draft reports. Part of the consultants' remit was to impart their expert knowledge of heritage railways to me. In the past, one of the issues for the RSC in employing consultants was that, once the task had been completed, they departed with their experience and only a report was left behind.

Since the graduate programme commenced, the RSC adopted a policy of requiring consultants leading audits to be shadowed by a graduate in order to gain experience and retain knowledge. In this regard, I followed what was being asked through the audit questions, checked and inspected, and learnt the purpose for checking certain areas. I also learnt about the specific risks and priorities in heritage railways, and the differences between them and their main line equivalents. This project produced eight audit reports (one for each heritage railway), a summary report, and also a guidance document for the safety certification of a heritage railway based on its SMS.

Following the audit I was tasked with project managing the safety certification of each of the heritage railways and closing the actions arising from the audit. Currently, conformity assessment of SMSs submitted by five of the self-contained heritage railways is completed, and safety certificates have been granted. At the time of the audit, one of the heritage railways was not operational, and two others have not yet achieved safety certification.

In May 2011 Commission Regulation (EU) No. 445/2011 was published which laid out the system for certification of Entities in Charge of Maintenance (ECM) for freight wagons. This European Regulation is mandatory, requiring all freight wagons to have a registered certified ECM in the National Vehicle Register (NVR) in order to operate in the EU after a specified date.

I was tasked with managing the project for certification of Iarnród Éireann (Irish Rail) as an ECM, and a specialist engineer was engaged from TÜV Rhineland to provide me with guidance and support. On the job training and also formal training sessions were provided by the specialist as the project progressed. I quickly started to take on

project management tasks; coordinating meetings and acting as the key point of contact. Guidance documents and certification procedures were developed and published by the RSC along with the required templates.

A project programme was produced and agreed with the railway followed by an initial audit plan. Over a period of two years the railway made improvements in working towards full compliance with continuous communication and meetings with the RSC. Stage 1 and Stage 2 audits were conducted, followed by a further Stage 2 audit due to a number of non-conformities found. After the second Stage 2 audit the RSC was in a position to issue a Certificate.

Following on from this, the year one surveillance audit was performed and I am currently ECM project manager for the RSC and I am now competent to lead ECM audits. As part of this process I attend ERA meetings which are valuable to ensure the RSC's interpretation of ECM Regulation is consistent with other NSAs. This provides a forum to discuss with other NSA representatives how their respective Member States have resolved issues they have encountered. The RSC are also encouraging the railway sector in Ireland to move towards voluntary ECM certification for locomotives and passenger stock.

In 2014 I was involved in an audit of the Maintenance and Operation of the Traffic Control and Signalling System on the Iarnród Éireann (Irish Rail) network. This was still a relatively new area to me, but with the experience of the auditing process, the MSc module in signalling and control equipment completed, and the training for the IRSE exams under my belt, I was confident to proceed. Later in 2014, I led an audit on the Management of Tram Maintenance which I was considered competent to undertake given the ECM experience, the many rolling stock training sessions I attended, and the various day to day rolling stock jobs I had already undertaken with the RSC.

Study Tour to USA

It is the policy of the RSC to maintain a world-wide network of contacts for the purpose of continued learning and sharing of railway information. It is appreciated that operational risk, resultant incidents and accidents, and railway development are not geographically constrained. I benefitted from this policy as one of two graduate engineers who were selected to go on a five-week study tour to the USA in April-May 2014.

The trip was organised around a need for training on Electro-Motive Diesel (EMD) locomotives of which the Iarnród Éireann (Irish Rail) fleet contains two types. Other elements of the trip were organised by the director of the Association of American Railroads (AAR), Mike Martino, who planned and coordinated various activities based on our needs, and put us in contact with leading industry experts. Activities undertaken during the trip were as follows:

- Locomotive courses at EMD training centre, La Grange, Illinois,
 - AC Locomotive Electrical Systems,
 - Locomotive Diesel Engine (Technical),
 - Locomotive Diesel Engine (Practical).
- Visits to Metra system, Chicago, and facility tours including depots, a signal cabin and control centre,
- Meeting with Amtrak staff followed by a train journey on the *California Zephyr* from Chicago to Denver, including a two hour head end ride en-route,
- Visit to the AAR Transport Technology Centre Inc. (TTCI), Pueblo, Colorado,
- Visit to the heritage Durango & Silverton Railway with a facility tour including the station and workshops,
- Visit to Union Pacific (UP) Proviso Yard, Illinois, with a facility tour including depot, hump and departure yard,
- Visits to Chicago Transit Authority (CTA) control centre and two workshops.

Of the three courses we attended at EMD, the first was based on the SD70ACe locomotive. Other areas were covered during the course to take account of student needs, including DC traction systems, with a particular focus on Iarnród Éireann locomotives. The micro-processor power control system of the SD70ACe very closely resembles the Irish 201 Class locomotive electrical system.

The second and third courses covered the theory and practical aspects of the EMD two-stroke diesel engine. The 645 and 710 engines are built on the same design concept and, apart from the 1-inch increase in stroke of the 710 engine, the most obvious differences are in the size/capacity and position of the supporting equipment such

as pumps, filters and turbocharger. The operation of these engines was also discussed in detail and, towards the end of the second course, we were given a tour of the factory facility where the engines are built, which supported the theory very well. During the week there was a large amount of class participation which was of great value to us as there were some very experienced people attending the class.

During the third course the engine which had been discussed in theory the previous week was disassembled, checked, and reassembled in accordance with EMD maintenance instructions. Some issues were intentionally existing in the engine for us to find and fix, and other issues were intentionally left behind allowing us to discuss and see - in a very practical way - many of the problems that can develop and mistakes that can be made during maintenance. One of the most important practical exercises that we undertook during this course was the "one-revolution" inspection of the engine.

During our time in Chicago, the Safety Manager of Metra, Hilary Konczal, arranged a number of visits for us. These visits gave us the opportunity to discuss with Metra their system and to explain our jobs in Ireland, in particular how we interact with our respective railways. We visited the 49th street depot, where approximately 17 locomotives and 150 carriages are maintained. During this visit we were given an overview of some current projects underway at the carriage overhaul facility. We were also invited to attend the Metra daily operations review meeting. The purpose of this meeting is to review the previous day's performance, delay causes, and other issues such as crime. All Metra locations and departments are represented by senior management, with approximately 70 participants in all. These meetings are specifically brief with a run time of about 15 minutes.

In addition, we visited the Metra CTC building, beside which there is an operational signal box which has been operating without modification since it was built in 1907. A head end ride took us to Fox Lake, a route which involves the Metra service passing over CP, CN, UP and Amtrak networks. The level of route knowledge required by drivers is significant as all of these networks have their own individual operational and signalling characteristics.

We travelled by train from Chicago to Denver on the *California Zephyr*. As we were travelling with the crew, we were able to observe their preparation for the service and also accompany them as they prepared the rolling stock. A head end ride followed, where we experienced the train operation from a driver's perspective. We travelled south from Denver to Pueblo where the team at the TTIC provided insights into:

- Vehicle-track interaction and derailment investigation,
- Railway communications and train control,
- Testing of rolling stock for crash performance.

On completing our visit to Pueblo, we headed west to the Durango & Silverton Narrow Gauge Railroad (D&SNRG) where we visited the maintenance facilities. The D&SNRG have endeavoured to keep practices at this facility as traditional as possible. Some of the items covered during the visit included:

- A discussion on the origin and engineering of the rolling stock,
- The development of the roundhouse and turntable,
- Guidance on how the rolling stock is maintained and how staff competence is managed.

On returning to Chicago we first spent time with Union Pacific at Proviso where we viewed the hump yard, the control tower, and the running lines where final departure checks are made. This was followed by a visit to the control centre of the Chicago Transit Authority, which is used to control rail and bus movements. It is an advanced facility which has the capacity to manage varying types of crises and also provides system resilience to public transport services. We also visited the CTA rolling stock maintenance facilities in Skokie and Howard where an understanding was obtained as to how a major metro system operator manages to maintain services whilst operating under severe weather conditions and constrained infrastructure.

Over the five week period many contacts were made and much was learnt. Some of the learning was specific to North American railway practice, such as the variety of signalling systems and some of the operating principles, but the majority of what we learnt was of equal relevance to European railways.



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CONCLUSION

Michael began his railway career after completing an engineering degree and with no prior railway experience. Through the RSC graduate development programme he has experienced an accelerated level of knowledge acquisition. He has gained experience in a wide range of railway disciplines in the three years that he has been with the RSC. He is now deemed competent in supervision activities and ECM auditing, and all inspection activities within the RSC's remit, including interviewing and conducting post incident inspections. Focussed training in rolling stock and in railway signalling and control have developed his specialist knowledge for the role he has as a railway safety inspector. All graduates on the programme have received similar core training and have each had their own experiences. Each graduate has developed their own specialist areas, and all have grown their railway knowledge and experience to become integral members of the RSC team, each with their own projects and responsibilities.

Table 2 – Distribution of specialist knowledge amongst the graduates

	Formation & Track	Bridges & Tunnels	Level Crossings	Traction Power Supply	Signalling & Telecoms	Diesel & Electric Locos	EMUs & DMUs	Passenger Coaches	Freight Vehicles	Light Rail Vehicles	Rules & Regulations	Planning & Timetabling	Human Factors	Heritage Railways	Cableways	Railway Economics	Legislative Framework	Occupational Safety & Health
I-1	o	•								•		o					•	
I-2					•	•	•		•	•				•				
I-3				o		•	•	•		•					o			
I-4	•	•	•								o	•				•		
I-5	o										o		o	•	o			
I-6			o	o	•						o							

• Well-developed level of expertise

o Expertise under development

Each of the graduates is subject to a quarterly review of progress, which is conducted jointly by Engineers Ireland and the RSC. The knowledge that has been gained through the academic aspects of the programme, and the training that has been undertaken on specific railway topics, has already enabled the RSC to considerably reduce its reliance on external consultants. The graduate development programme is equipping the RSC with the railway knowledge and skills necessary to undertake the tasks that are mandated under European and national legislation.

The development of knowledge and skills is not isolated to those within the graduate programme; as an organisation the RSC is continuously striving to develop and enhance the professional capability of all its Inspectors. As the railway continues to develop and advance, the need to stay abreast of new technologies and practices is as important as a well-rounded knowledge of the core principles of railways. Railway knowledge, and the continuous enhancement of it, is fundamental for the successful regulation of railway safety.