

Evolving Challenges in Military Engineering. How Can Small Military Organisations Meet These Challenges?

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The security environment today is becoming increasingly complex. Interstate warfare has erupted in Europe for the first time in a generation, great power competition is on the rise, and instability in the developing world is growing as a result of the pressures of climate change. This paper analyses how military engineering has adapted to these threats and what future adaptation is required to meet the challenges of tomorrow. Military engineering represents a uniquely broad set of capabilities that are essential enablers of military operations. This paper takes a holistic view of these capabilities, using case studies to track how operations have affected the organisation and employment of military engineers. Examining conventional warfare from Iraq to Ukraine, peace operations from the Balkans to the Sahel, and counter-insurgency operations in Afghanistan, as well as humanitarian operations globally, it identifies the key lessons from these crises and the effect they have had on engineering capabilities.

The paper concludes by offering several methodologies for addressing capability gaps within constrained resources. Ireland is significantly out of balance with comparator nations in terms of the size of its military engineer capability and the paper highlights several doctrinal developments that should be considered as Ireland builds its next force model. While it may be possible to prioritise or relegate some capabilities, doing so should be done with the full acceptance of the risks in terms of overall defence capability, as well as the risk to our deployed soldiers and those we protect.

INTRODUCTION

In June 2022, the Chief of the General Staff of the British Army raised eyebrows during a speech with his remark “you can’t cyber your way across a river” (Sanders, 2022). His intention was not to denigrate the importance of building essential new capabilities; they came in the wake of Russia’s invasion of Ukraine and shortly after a disastrous river crossing operation that had a significant impact on the Russian offensive (Michaels, 2022).



The war in Ukraine is providing a proving ground for new military capabilities and technologies that are putting tactics, techniques and procedures developed in the twentieth century to the test. Classic military engineering operations such as bridge demolitions, gap crossing, mine warfare and fortifications have been broadcast across the world and are being scrutinised by military experts to learn lessons for future operations.

The recent report of the Commission on the Irish Defence Forces (CODF) (2022) could have a transformational effect on Ireland's security capabilities and as a key component, military engineering must be prepared for transformation to support future requirements. The report outlines four trends that will affect the future security environment: Increased great power competition; continued instability on Europe's borders; increased use of hybrid forms of aggression; and a more demanding environment for troops deployed overseas. Each of these trends will have a direct effect on the requirement and capabilities of military engineers. By analysing the key factors that have affected the priorities of the military engineering focus, this research will identify what capabilities Ireland, with its small Defence Forces can aspire to.

Literature Review

This paper will take a holistic view of military engineering capabilities and structures; however, there is minimal available literature that takes this approach. The majority of research emanates from practitioner journals such as *The Royal Engineers Journal* in the UK and *Engineer* in the US. While they may contain obvious bias, they are nonetheless important sources and contain many useful bodies of literature that examine specific military engineering capabilities. This section will briefly examine two such studies, and another that examines the effects of a recent reorganisation on the military engineering capabilities of a medium sized NATO member. It provides insight into some of the issues that future military engineers must contend with such as modernising equipment, overcoming obsolete doctrine and integrating modern threats.

In terms of the future of military engineering capabilities, Maj Matthew Littlechild (2021) explores a future option for replacing land mines with an Area Access Control (AAC) system that is discriminant and non-persistent. Littlechild is a senior engineer officer in the Canadian Armed Forces who completed this research as part of the Master of Defence Studies, Joint Command and Staff Program of the Canadian Armed Forces. He argues that state signatories of the Anti-Personnel Landmine Convention (APLC), also known as the Ottawa Convention, now have a capability gap that must be filled with new technology without the humanitarian legacy issues of mine warfare. This model combines a Command-and-Control system with a mix of sensors; command operated lethal effectors and autonomous non-lethal effectors including loitering munitions, anti-armour smart mines and Wide Area Munitions. While this study was deliberately vague in order to remain unclassified, its use of a case study to war game how an AAC model could be employed against a Russian invasion of the Baltic States provides a useful insight into new technologies that military engineers will have to master in order to evolve their counter-mobility capabilities.

In respect to mobility, and specifically wet gap crossing, Watling's (2022) report on the Royal United Services Institute (RUSI) Waterway's Conference 2022 provides several prescient lessons. Dr Jack Watling is a Senior Research Fellow for Land Warfare at RUSI. The conference examined how the approach to crossing waterways needs to change to meet the modern threat environment. It

highlighted the major reduction in this capability across NATO since the end of the Cold War as well as an almost complete lack of amphibious vehicles in NATO (in contrast to Russia). The lack of integration between combined arms training was highlighted: “if gap crossing is viewed as an ‘engineer sport’ it was unlikely to be successful in practice” (Watling, 2022, p.4). This was particularly relevant during discussions on the significant expansion of surveillance capabilities, including space-based sensors that are not adequately mitigated against in current doctrine. This report highlights how Cold War doctrine and crossing equipment must be updated, as well as the requirement for a multi-domain, combined arms approach to these important operations.

From an organisational perspective, Cibulova *et al.* (2021) examine the effect of a recent significant reorganisation of engineer forces within the Armed Forces of the Czech Republic, focusing particularly on the army’s mobility capabilities. The authors are academics with the Department of Engineering Support, University of Defence in the Czech Republic. Each has significant military and civil engineering experience with research focusing on decision-making processes and management of engineer operations. The reorganisation in question resulted in a decrease in mobility support capabilities within the engineer regiments in favour of a slight increase in the mobility support capabilities within infantry battalions. They argue that the failure to address equipment requirements, particularly earth moving machinery and modernised bridging led to an overall reduction in mobility support capabilities to the army as a whole. The article makes several recommendations, however, as the focus is on mobility operations, it fails to address the ability of this reorganisation to cater for the multiple other engineering skillsets such as fortification construction or obstacle emplacement.

Research Lacunae

Having examined existing academic literature, it is clear that there is a significant lacuna in terms of research on military engineering capabilities. While professional military engineering bodies have written much, very little peer-reviewed literature exists on this topic. Additionally, the majority of literature that does exist usually focuses on narrow areas within the military engineering sphere, such as gap crossing, mine warfare, fortifications, etc. By only focusing on specific capabilities, there is a danger that the breadth of military engineering capabilities can be overlooked. There is, therefore, a need to research the military engineering contribution to operations ‘in the round’. Only in doing so, is it possible to identify the most suitable organisation of military engineering forces needed to build and sustain those capabilities at the required levels of readiness. This is particularly relevant for small military organisations with limited resources that cannot be expected to field the full gambit of engineer capabilities. There is therefore a need to prioritise what can be delivered and what must be outsourced, either to military partners or to civilian contract.

Research Question

This research proposes the overarching question: how can a small military organisation, such as Ireland’s, meet the growing need for military engineering capabilities as they evolve in line with military operations and technological advancement? There are many new challenges that military engineers will face in the coming years, as well as some old challenges that have been resurrected in modern, nuanced form. For a corps whose *raison d’être* is to shape the physical operating environment, these challenges will stem from both the international security as well as the natural environment and will be affected by the strategic direction in which Ireland will align itself in the

coming years. In order to assess how Ireland should approach these challenges we must first assess how military engineers have adapted and contributed to military operations since the end of the Cold War. We must then examine how military engineers will have to adapt in the future. Finally, this must be rationalised to an Irish context by analysing how Ireland should prioritise the military engineering capability requirements it needs.

Sources

Documents such as the White Paper on Defence (Department of Defence (DOD), 2015) as well as the Report of the CODF (2022) outline current defence policy, the security context, and likely future trends from an Irish perspective. Academic literature and open-source government reviews of foreign military operations will be used to track the trends in warfare over the past thirty years and identify appropriate lessons from the military engineering sphere. Relevant military doctrine will also be examined, from both Irish, NATO and other foreign militaries. Finally, open-source data on selected militaries will be used to compare Ireland's military engineering capabilities.

Methodology

This paper will utilise a mixed methods approach, focusing on qualitative analysis of primary and secondary documentation, supported by quantitative data of comparator armed forces to provide firm comparisons with the Irish Defence Forces. A review of existing literature will track the evolution of military engineering priorities. Thereafter, case studies will analyse the contribution of military engineers in relevant operations and in different environments using NATO military engineering doctrine as a framework for comparison. Case studies allow for flexibility in terms of methods of data collection while also having the necessary rigour to deliver credible results if they are conducted with proper attention to context (Pearson *et al.*, 2015). A mixture of qualitative and quantitative data gathered from selected armed forces will be used to compare military engineering capabilities as well as the benefits and rationale of differing approaches to organisational design.

McManus's (2022) model for a Capability Development Planning Process (CDPP) will be used as a framework for identifying capability requirements, gaps, and priorities for future military engineering. This model was adapted from NATO and EU processes for Irish defence requirements as seen in Figure 0-1 below.

Evolving Challenges in Military Engineering

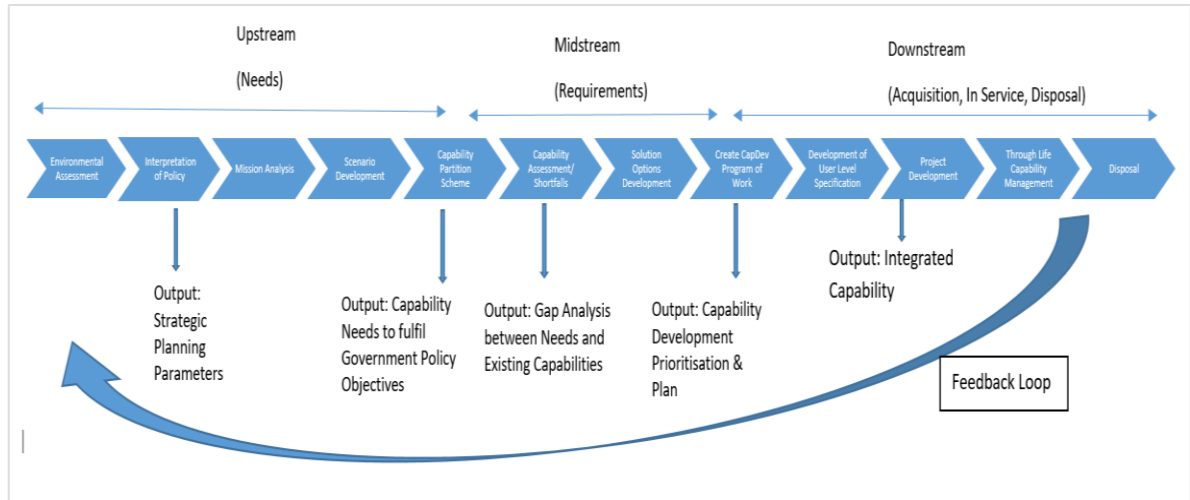


Figure 0-1: Illustrative CDPP model (McManus, 2022)

In this model, the 'Upstream' stage commences with an assessment of the security environment and interpretation of policy and political guidance. Next, Mission Analysis is conducted, using lessons learned from past operations along with existing doctrine and new operational concepts, assessed against identified scenarios. This will "identify what should or could be done in order to achieve determined defence policy objectives" (Duffy and McManus, 2022, p. D-3). Finally, capability needs are determined to meet the policy objectives in these scenarios.

Using this framework, Part One will examine how military engineers have evolved in order to best contribute to military operations since the end of the Cold War. It will briefly touch on key conflicts such as the Gulf War and peace operations in the Balkans before focusing on their contribution to counter-insurgency operations in Afghanistan, forming the basis for the Mission Analysis stage. Part Two uses recent government documents to identify policy and future security trends, before assessing how military engineers must adapt in the future, using three current scenarios to draw lessons: conventional warfare in Ukraine; peace support operations in the African Sahel; and Humanitarian Assistance and Disaster Relief operations globally. Finally, Part Three will conduct a Capability Gap Analysis by conducting a comparison of Ireland's military engineering capabilities to other similar armed forces and to identify potential gaps in Ireland's capabilities. The paper will conclude with recommendations as to how these gaps could be addressed.

PART ONE. Evolution

"I will ignore all ideas for new works and engines of war, the invention of which has already reached its limits and for whose improvement I see no further hope."

Julius Frontinus, Chief Military Engineer to Roman Emperor Vespasian, AD 70 (White, 2005)

Despite Julius Frontinus' prophesy, engines of war, along with military engineering itself have continued to evolve and have done so rapidly in the last 100 years. The character of conflict is ever

changing, and military forces must adapt quickly to succeed. As a key enabler, military engineers are no different and must continuously evolve to remain relevant and capable of fulfilling their roles and objectives. NATO's joint doctrine defines military engineering as "a function in support of operations to shape the physical operating environment" (NATO, 2021, p.1-2). This broad definition provides some warning as to the extensive scope of military engineering tasks. It further outlines that military engineering is an inherent part of every joint function and that it supports each function as can be seen in Figure 1-1 below. Given the breath and complexity of these tasks, even the largest military organisations must prioritise their military engineering efforts. Therefore, as armed conflict has evolved since the end of the Cold War, there have been several major shifts in focus of military engineering globally in order to adapt to, and support operations as strategic priorities changed.

This part will determine how military engineers have evolved and how they have contributed to operations since the end of the Cold War. Focusing on organisation, structures, and capabilities, it will briefly touch on key conflicts such as the wars in the Gulf and peace operations in the Balkans, before focusing on their contribution to counterinsurgency (COIN) operations in Afghanistan, where the full spectrum of engineer tasks was carried out.

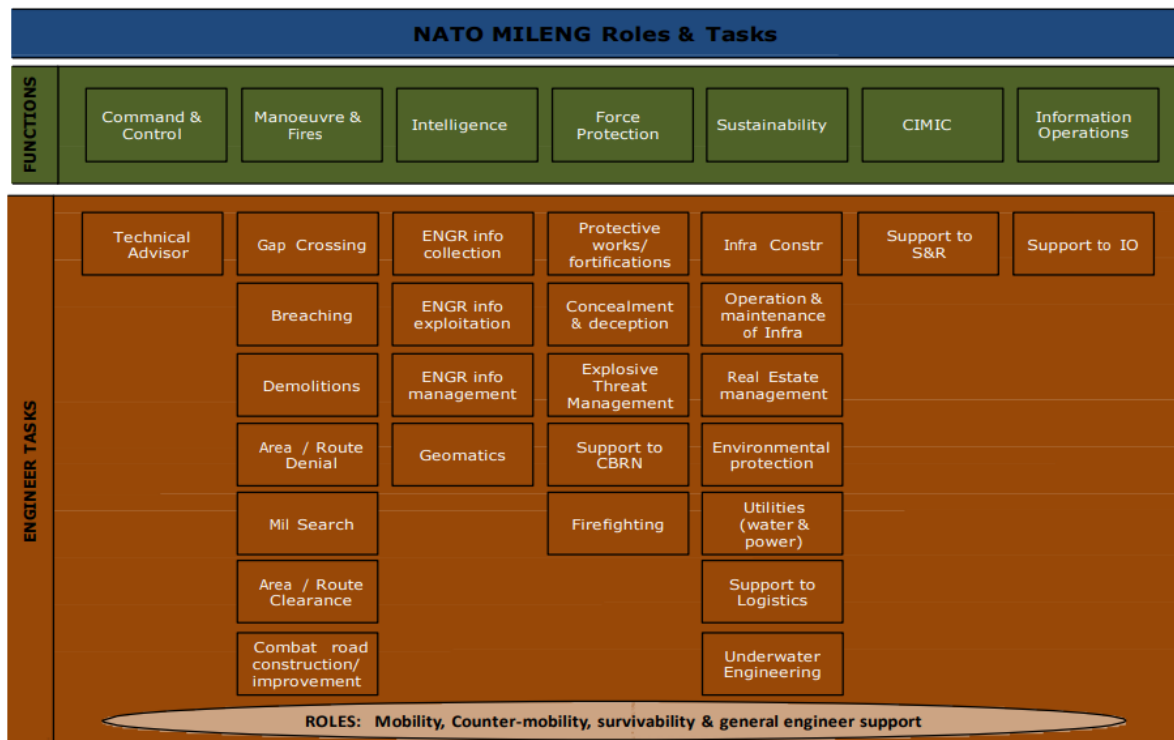


Figure 0-2: Framework of MILENG Roles and Tasks (NATO, 2016a)¹

The Peace Dividend and 'New Wars.'

In his history of the Royal Engineers (RE), Napier (2005) notes that for the majority of the Cold War, most militaries organised their engineer forces into battalion/regimental sized formations. Prior to

¹ S&R: Stability and Recovery; IO: Information Operations. CBRN: Chemical, Biological, Radiological & Nuclear

this, most had been organised as independent company/squadron sized units. Engineer regiments were allocated to the manoeuvre divisions. Normally a field engineer company would support a brigade, with further field and support companies at divisional level containing heavier equipment such as bridging and construction capabilities. As Warsaw Pact forces grew, so did the expectation of the large-scale destruction of limited nuclear war with widespread use of landmines. Together with the introduction of Air Land Battle, most militaries evolved their organisations to allow brigades to operate more independently, with minimal divisional support, and therefore expanded their engineer capabilities with regiments at brigade level. These regiments were normally organised as either 'Close Support' regiments, who supported the fighting echelons, and 'General Support' regiments, who supported the whole force (e.g., route maintenance, EOD, airfield damage repair). For the British Army, the Cold War ended before these reforms came into place; however, the First Gulf War provided an opportunity to put the concepts into practice. Napier asserts that the "integration of close support had to be contrived in-theatre to meet the need" (Napier, 2005, p.221), however they were codified in army structures during the 1990s. In total, the 1st (British) Armoured Division with its two manoeuvre brigades had two field engineer regiments, one armoured engineer regiment, one general support regiment, three field squadrons, one field support squadron, one EOD squadron and one topographical squadron under its command (Hamilton, 1991). During this short conflict, engineers were engaged in the full remit of tasks, from establishing operating bases and defensive positions during the defensive phase of the war, to clearing Iraqi obstacles, laying minefields, clearing explosive ordnance, and restoring public utilities after the conflict (US Army Corps of Engineers, 2002). It demonstrated the importance of appropriately resourced, multi-skilled and adaptable engineer forces.

While this conflict demonstrated the effectiveness of Cold War preparations for conventional warfare, the 1990s were mainly characterised by 'New Wars'. UN forces initially led peace support operations in the Balkans before being succeeded by the more robustly mandated, NATO-led Implementation and Stabilisation Forces (IFOR/SFOR). Again, military engineers played a key role, however in contrast to operations in Kuwait and Iraq, the emphasis in the Balkans was on force support tasks as well as humanitarian and reconstruction assistance (Grindle, 2013). These tasks included the construction and provision of services to UN/NATO bases, but also included reconstruction of major lines of communication and the replacement of bridges damaged or demolished during the conflict. In total 60 bridges were replaced by IFOR (Napier, 2005). This period coincided with a growing worldwide awareness of the indiscriminate harm caused by landmines. Championed by celebrities such as Princess Diana, this culminated in the signing of the APLC, or Ottawa Convention, in 1997, which banned the use of these mines, although failing to further regulate the use of Anti-Vehicle Mines. With their widespread use during the conflicts in the Balkans, demining and mine risk education became an important task for engineers.

Iraq 2003: Joint Force Engineering in practice

Operations in the previous 20 years, as well as influencing the size and type of engineer forces, also created lessons in how engineers were controlled. Several NATO countries began formulation of a doctrine on Joint Engineering, which was first published in 2003 as AJP-3.12(A). This coincided with the US-led invasion of Iraq, which was the first opportunity to put the concept to the test. From the British perspective, Operation *Telic* provides an excellent insight into the organisation, employment,

and control of engineer forces for an expeditionary conventional campaign. Contemporary sources writing shortly after the end of major hostilities demonstrate firstly, the importance of the Joint Force Engineer Operational Concept (JFEOC), while also alluding to the effects achieved by the correct employment of engineers.

Joint Force Engineer Operational Concept

The JFEOC (UK Ministry of Defence (MOD), 2006) emphasised the following principles of employment of engineers: Single Point of Engineer Advice at each major command and control node; Centralised Co-ordination, Decentralised Execution; Allocation of Priorities to ensure concentration of force and economy of effort; Early Involvement in Planning and Reconnaissance Activities to avoid delays in assembling the required resources; and the Importance of Interoperability. To achieve these principles, it codified the ad-hoc organisational arrangements seen during the first Gulf War, with divisions being allocated one Close Support Engineer Regiment for each Brigade as well as a General Support Regiment at divisional level. These elements would be commanded at divisional level by a Commander Royal Engineers (CRE) and at Brigade level by the Commanding Officer of the regiment. Where a Joint Command was established, it would include a Joint Force Engineer Cell with sufficient staff to provide engineer advice and input into the planning activities of the standard planning cells in the headquarters.

Division level engineering in perspective

In his report to the Corps in December 2003, the Engineer-in-Chief reported that 54% of the corps had deployed on Operation *Telic*, representing 14% of the land component. It was the largest deployment since World War Two and required the deployment of all operational stocks of bridging and water supply equipment. Urgent operational purchases of many other key equipment capabilities, including deployable accommodation were also necessary (Innes, 2003). The majority of these units were part of 1 (UK) Armoured Division's Divisional Engineer Group. Additional General Support Regiments also supported the Joint Logistics Command, and Air Component with an EOD Squadron, Geographic Regiment, and additional Specialist Teams Royal Engineer (STRE)² at Joint Force level. In total, this amounted to three close support regiments, three general support regiments, two specialist regiments and six STRE to support three brigades, the logistic command, and the air component. This totalled almost 4,000 engineer troops (Rider, 2010). The Joint Force Engineer (JFEngr) had command of engineer units at the joint force level and was given operational control of the remaining assets within their respective commands (Fairclough, 2003). This was deemed essential for efficient resourcing across the components.

Lessons Identified

Carruth (2003) outlines the main issues at the Joint Logistics Command. As CRE, he had an engineer staff of ten personnel and managed the construction of all camps, ranges, and a field hospital using its general support engineers and contractor support. The scale of the task at hand was enormous – to prepare for and receive 22,000 troops, accommodate them in the desert, and then redeploy and replicate in Iraq after major hostilities ended. Command and Control appeared to be problematic

² Specialist Teams Royal Engineers are small highly specialised teams of officers and NCOs who supply infrastructure consultancy, engineering design, programme and project management, contract management and facilities management in areas such as aviation, Force Protection Engineering (FPE), fuel, water development, power, and construction materials.

throughout. Units were frequently detached back and forth between the Joint Logistic Command and various logistics brigades, depending on the task type and location, which led to confusion and inefficient communications. However, it was considered that “grouping RE capabilities under the Divisional Engineer Group was essential to permit theatre-wide prioritisation of limited resources” (Carruth, 2003, p.252). The logistics operation highlighted a number of lessons such as the need to properly resource the construction of dedicated routes in the deserts. The availability of sufficient electrical distribution equipment at unit level as well as sufficient electricians to support them was also a problem. Lessons were also learned in the deployment and resourcing of tented camps, as well as the adequate provision of plant machinery.

In his report, Colonel James OBE (2003, p.25), the Division Engineer, noted that the organisation “was the total validation of the level of close support that a squadron brings to its supported battlegroup”, proving the concept of a close support regiment per brigade. The support allowed flexibility in tasking while maintaining sufficient concentration of force. For example, engineer assets had to be re-deployed to support the Joint Helicopter Force who deployed without engineer support, but this was simplified through liaison with the Joint Engineer Cell. The General Support Regiment from Joint Logistics Command and several STREs were also able to be reallocated to 1 (UK) Armoured Division for the stabilisation and reconstruction phase, to support restoration of services in Iraq. However, he did note that Engineer Intelligence was a weakness compared to the US, as was the timely provision of logistics – “In many cases “just in time” failed, and failed badly” (James, 2003, p.258).

From an equipment perspective, the use of armoured engineer vehicles as well as general support bridging was considered a source of envy by the rest of the coalition. It was also notable that the US coalition’s rules of engagement forbade the use of anti-tank mines that were not capable of self-deactivation/self-neutralisation. Even those were seen as a weapon of last resort – a sign of the impact of the global advocacy movement of the late 1990s.

While the scale of this deployment can never be replicated by small organisations, the lessons outlined above have three important impacts on the Irish Defence Forces. Firstly, they provide a concept for how Irish engineer units would “plug-in” to multinational headquarters and the potential pitfalls to avoid if this was ever the case. Secondly, it provides a prescient example of the quantity and capabilities required of engineering units, particularly in the close support role, which cannot be outsourced to civilian contract. Lastly, it demonstrates the benefits of a ‘Single Point of Engineering Advice’ with a clear command and control structure to allow for the efficient use of those engineers available to the force.

Military Engineering in Afghanistan

This study focuses on the COIN element of the conflict in Afghanistan. The International Stabilisation Assistance Force (ISAF) was the UN mandated, NATO led, mission that was established after the 2001 invasion until 2014. At its peak, the force had 130,000 troops from 51 nations, including Ireland (NATO, 2022a). The UK contribution to the campaign was known as Operation *Herrick*.

The campaign brought several military engineer capabilities into focus. It was symbolised by the havoc caused by Improvised Explosive Devices (IED). It was also marked by the extensive use of 'Forward Operating Bases' (FOB) to dominate the area. These bases, their design, construction, layout, and protective measures were perfected over a decade of intense combat. Finally, traditional mobility support engineering remained critical for maintaining freedom of manoeuvre, while also contributing to reconstruction and development. As an example of one British Engineer Regiment's tempo, during their six-month tour in 2009, they "conducted over 450 EMOEs [Explosive Methods of Entry], built 13 bridges, 58 Forward Operating Bases/Patrol Bases/Command Posts, ... spent £17.5 million on aggregate, let £22 million of contracts and dealt with over 1,500 IED incidents." (UK MOD, 2014, p.3-7_1).

Close Support Engineering

Unlike the forces deployed during the Iraq invasion in 2003, ISAF forces, in the main, operated either on foot or in wheeled Armoured Personnel Carriers (APC). This represented a changing dynamic in terms of the focus of close support engineering towards a lighter and frequently dismounted close support role. An Irish officer who attended the Royal Engineer Troop Commanders course in 2000 spent most of their exercise time conducting 'battle runs' across Salisbury Plain in tracked FV432 APCs supporting armoured battlegroups in the attack and defence. When the next Irish student attended the same course in 2011, the emphasis had changed entirely to that of COIN centric, light role, dismounted close support tasks.

Lodge (2011), a troop commander with British forces in Afghanistan in 2010/11, provides a flavour of the diverse close support activities conducted by his troop. Battlegroup support consisted of providing EMOE teams for compound clearance, demolitions, bridge construction, and constructing hasty defensive positions. However, armoured engineering was also employed, with the British use of the 'Trojan' Armoured Vehicle Royal Engineers (AVRE) and the 'Python' explosive line charge to clear IED belts during Operation *Moshtarak* amongst others. Canadian engineers also deployed their Armoured Engineer Vehicle (like the AVRE) for clearing IED belts and demolition of enemy compounds (Holsworth and Dubois, 2009). The Dutch Armoured Engineer Company, part of the Dutch Battlegroup, integrated their Engineer Platoons with Infantry Companies to conduct close support, most frequently to search routes for IEDs on each patrol (Wiltenburg and Leeuwenburg, 2021).

One of the main lessons to come from the deployment, from a British perspective, was the requirement for multiple gap crossing capabilities at various levels, from short gaps to move vehicles over irrigation ditches, to the long-term replacement of bridges for the local population. Notably, the UK decided to return the Medium Girder Bridge to service, having been retired in 2008, given its flexibility and portability compared to the newer Automated Bridge Laying Equipment (ABLE). The Rapidly Emplaced Bridging System (REBS) was also procured by Royal Engineers for Afghanistan and subsequently procured by the Irish Defence Forces. The majority of bridges used are also in service with the Irish Corps of Engineers so lessons on their employment could be extremely useful for Irish mobility doctrine. However, the extensive use of EMOE is also an area worth further consideration by the Irish Defence Forces.

Force Support Engineering

Survivability has always been one of the core tasks of military engineers. For most of the 20th century, survivability has focused on expedient 'field fortifications' – battle trenches, command posts, weapons pits, etc. However, the threat from direct, indirect fires and IEDs in both Iraq and Afghanistan led to a significant shift. Together with a strategy to secure the population by dominating the area of operations with multiple small bases, much engineer effort during the conflict was taken up in the construction and maintenance of FOBs, Patrol Bases, and Check Points. These bases would become a target for insurgent attacks and many different solutions were implemented to reduce the risk to ISAF troops. This came to be known as Force Protection Engineering (FPE) and was part of a wider effort to universalise force protection techniques and procedures throughout NATO.

The particular threat from blast weapons required a more scientific approach to designing protected structures. Computer modelling and weapons effects algorithms were developed to provide accurate and efficient design solutions (Hambly *et al.*, 2015). The UK produced a detailed manual on FPE fundamentals, structures, and security systems (UK MOD, 2007) and NATO conducted several revisions of its own Force Protection standards, which included large contributions from military engineering. By 2016, NATO had standardised the process for classification and testing the effects of weapons on structures to ensure commonality amongst the alliance. The use of locally sourced materials was identified as the more logistically efficient method of construction versus importation of modular or prefabricated structures (UK MOD, 2014). Research was also conducted to underpin a better understanding of how these non-standard materials reacted to blast and penetration effects (Warren *et al.*, 2013). This data is invaluable to all militaries, especially those who may not have the resources to conduct such research independently, underpinning the importance of partnership and information sharing.

Most engineer units deployed dedicated specialists to design their bases with general support or construction engineers acting as the construction force. However, as the conflict intensified, these skills were devolved to lower levels with common practices promulgated. The vast majority of nations differentiated between their close support and general support personnel, with the latter containing a larger proportion of skilled artisans and design engineers. There was, however, a realisation that, due to the volume of tasks, a more blended mix of general and close support personnel was more efficient (UK MOD, 2014). Extensive use was also made of contractors and Locally Employed Civilians (LEC), particularly for larger bases. The UK headquarters, Camp Bastion, for example, employed approximately 400 contractors for routine maintenance. The maintenance for Canadian forces at Kandahar Airfield was provided by 60 civilian employees (Holsworth and Dubois, 2009).

However, as articulated by ISAF's Chief Engineer:

"The difficulty I had was that we had lots of engineers building military camps and building infrastructure and filling Hesco Bastion and building runways, but we had very few engineers delivering a reconstruction environment effect" (UK MOD, 2014 p.3-7_2).

Despite this there was significant reconstruction work completed. Provincial Reconstruction Teams (PRT) were established early in the campaign for this purpose and engineers were key to delivering infrastructure projects while also managing civilian infrastructure contracts. Engineers also

contributed as a by-product of security operations. For example, during Operation *Omid Haft*, along with many close support tasks, engineers repaired roads, closed insurgent tunnels under a canal and constructed a bridge for local use over the canal with a checkpoint to monitor the area (UK MOD, 2011).

C-IED (Counter – Improvised Explosive Devices)

While the C-IED fight was a whole-force responsibility, military engineers played a vital role. Royal Engineers had developed specialist search techniques during the Troubles in Northern Ireland (as had the Irish Defence Forces), much of which were adapted to operations in the Middle East. Other countries quickly realised the need to develop these tactics, techniques, and procedures (TTP) to protect their own troops as well as to support manoeuvre in their areas of operations. NATO eventually developed its own doctrine that closely mirrored that of the UK and by the end of the campaign, most ISAF contributing countries had a strong military search capability with modernised detection equipment, including military working dogs. It was one of the most high-risk activities undertaken by ISAF with a total of 22 C-IED team members killed in action and 76 wounded in the British Army alone between 2006 and 2014.

As an evolution of the predominantly dismounted route search techniques, Route Proving and Clearance was used extensively in both Afghanistan and Iraq. It involved creating integrated units with military search, Explosive Ordnance Disposal (EOD), Unmanned Aerial Vehicles (UAV), force protection and Mine Resistant Ambush Protected (MRAP) vehicles, some fitted with mine rollers and/or robotic arms for interrogating suspicious areas. It was used to good success as a vanguard unit, moving slowly in front of large convoys to ensure routes were clear of explosive hazards. While Ireland has several of these sub-systems, it has not yet produced a doctrine for a combined arms, task organised, mounted route clearance capability.

Structures and Adaptation

While no two nations had identical engineering organisations, similarities are evident. Those are the need to maintain engineer units at regimental/battalion level at a minimum; and the need for a central point of command and control for engineer forces. UK, Canadian, Dutch, and other smaller contributors maintained this command-and-control system from early in the campaign. However, the US did not implement this system until 2012 when their 411th Engineer Brigade assumed the role of Joint Engineer Command (Smith, 2012). This consolidated all engineer operations under one command, providing “all theater [sic] engineering support to IJC while working with regional commands, providing all theater [sic] tactical construction and assured mobility” (Smith, 2012, par.12).

At brigade level, the UK and Canada both deployed initially with a squadron of engineers (reinforced to 300 personnel in the British case) before quickly increasing numbers to Engineer Regiment level (CMEA, 2018 and UK MOD, 2014) with the Regimental Commander also acting as the JFEngr. The composition of these units regularly changed as they adapted to the prevailing situation, however an example of one UK unit is seen in Figure 0-3 below. Of note in this organisation is the absence of the C-IED capability that was separated from the JFEngr Group from 2009-2013 into a separate C-IED Task Force as it expanded in line with the increasing threat. Similarly, Canadian engineer units were organised into a Close Support Squadron, which mixed armoured engineers,

route clearance teams and field engineers; a C-IED Squadron, which contained EOD/Search and exploitation teams; and a General Engineer Support Squadron, comprised of military and civilian construction experts, as well as firefighters (Holsworth and Dubois, 2009).

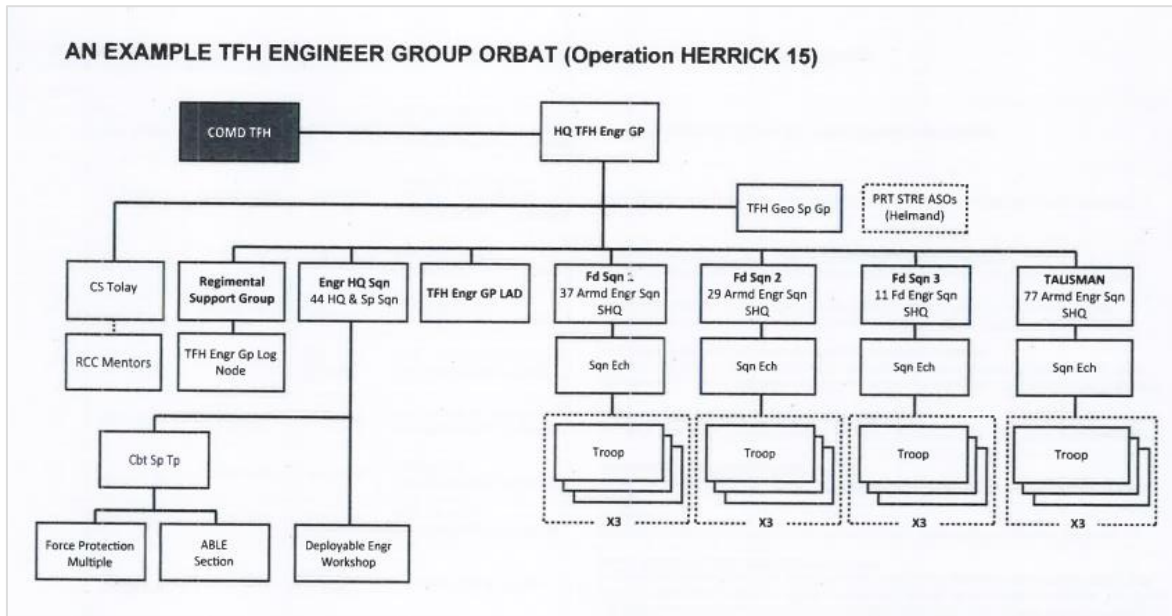


Figure 0-3: Typical organisation of an ISAF Engineer Regiment (UK MOD, 2014)

Both UK and Canadian organisations included dedicated nodes for planning engineer operations within their supported units. In the British case, this was the Battlegroup Engineer, an engineer captain seconded to each battlegroup for the duration of the tour to provide permanent dedicated engineer advice and planning to the Battlegroup's operations staff. Similarly, the Canadians established an Engineer Support Coordination Cell (ESCC) in each supported battlegroup, however in their case they normally gave a squadron under operational command (OPCOM) to the battlegroup, a higher command relationship than the UK, although the Engineer Regiment maintained technical control (Coombs, 2016). One of the key lessons identified by the British Army was the importance of these single points of advice and planning at each level of command, and how these structures must be maintained and reinforced.

Lessons Identified

The campaign in Afghanistan provides a fascinating insight into the use of military engineers across the full spectrum of operations, from stabilisation activities to high tempo conventional operations such as Operation *Moshtarak* or Operation *Panther's Claw*. In a contemporary environment where the lines between war and peace are becoming increasingly opaque, it provides important lessons for smaller military organisations in terms of the importance of properly resourcing and organising its engineers to achieve the required effects. The rapid development of several important capabilities is also likely to remain relevant in years to come. The lessons identified through the extensive force support activities in Afghanistan are directly relevant to Irish operations overseas where similar threats exist to a greater or lesser extent. Key to this is an understanding of the utility of engineers,

both general and specialist, from both a force protection, civil-military cooperation, and disaster relief perspective.

Conclusion

Over the last 30 years, there has been a significant evolution in both the organisation and capabilities of military engineers. From an almost total focus on armoured engineering against the Warsaw Pact, through peace support operations around the world, and almost 20 years of COIN operations in Afghanistan and Iraq, this operational experience has provided the testing ground for new concepts and capabilities.

The wars in the Gulf provided an opportunity to trial new organisational and command and control structures, while also demonstrating the importance of maintaining a properly resourced engineering capability. Peace Operations in the Balkans provided a proving ground for expeditionary force support engineering that would lay a good foundation for higher tempo operations in Afghanistan. Finally, COIN operations have allowed those capabilities to evolve further. Capabilities such as FPE, Military Search, C-IED, dismounted close support engineering and bridge construction have evolved to remain effective in a contemporary operating environment where front lines are not easily delineated. Logistical issues from the Gulf War to Afghanistan also demonstrated that reliance on civilian contract, or 'mechano style', prefabricated solutions is no substitute for appropriately resourced, multi-skilled and adaptable engineer forces, designing by first principles.

The lessons learned from this period of conflict demonstrate the continued relevance of those engineering principles: a Single Point of Engineer Advice; Centralised Co-ordination, Decentralised Execution; Allocation of Priorities; Early Involvement in Planning and Reconnaissance; and the Importance of Interoperability. In a future operating environment, that appears more "congested, cluttered, contested, connected and constrained" (UK MOD, 2015, p.viii), smaller military organisations will need to maintain pace and continue to evolve to remain relevant and effective.

PART TWO. Emerging challenges

"The difficult we will do at once; the impossible will take a little longer. For miracles we like a month's notice!"

Maj Gen William Hasted RE, Chief Engineer, 14th Army, Burma 1945 (Slim, 1956)

Having assessed how military engineering has evolved since the Cold War, it is now necessary to examine some of the pertinent emerging issues that will challenge military engineers and demand future adaptation. Predicting future security requirements is fraught with challenges. The concept of 'Horizon Scanning' was introduced to the business world by Ansoff (1975), a technique that has permeated the defence and security realm in recent years. It is defined as "the acquisition and use of information about events, trends and relationships in an organization's external environment, the knowledge of which would assist management in planning the organization's future course of action" (Choo, 2002, p.84). However, as former US Secretary of Defence, Robert Gates noted of the USA's

track record on predicting conflict since Vietnam: “we had no idea a year before any of these missions that we would be so engaged” (Cohen *et al.*, 2020, p.1). Few major defence reviews predicted conventional war in Europe, but it is also important not to over emphasise ‘black swan’ events as representing paradigm shifts in military affairs. However, as Major General Hasted noted in 1945, change takes time and in an increasingly volatile, uncertain, complex, and ambiguous world, the capacity to flexibly respond to unforeseen events, the Rumsfeldian ‘unknown unknowns’, will remain a central requirement for all military organisations.

Most studies by large western organisations tend to agree on relevant trends (Cohen *et al.*, 2020) and so the themes within this part have been selected due to their commonality across several pertinent reviews. The report of the CODF (2022) echoed the updated White Paper on Defence (DOD, 2019) that the threat and risk environment will remain complex and unpredictable. This was made abundantly clear with the Russian invasion of Ukraine within weeks of the report’s publication. Both documents also highlight the instability in the Sahel region of Africa as well as climate related risks, emergencies, and natural disasters. Similarly, the UK (UK MOD, 2015) identified five core characteristics that will have implications for Defence: technology; access; blurring of national and international threats; the urban and littoral challenge; and Humanitarian Assistance and Disaster Relief (HADR). Finally, the EU’s Strategic Compass (EU, 2022) highlights similar trends while also emphasising the return of large-scale warfare in Europe. Based on these studies, three areas warrant further examination in relation to military engineering: the changing character of conventional warfare; the requirement for more robust peace support operations, particularly in relation to the Sahel region; and an increasing requirement for HADR. These areas encompass the majority of military engineering tasks within the roles of mobility, counter-mobility, survivability, and general engineering, as can be seen in Figure 0-1 below.

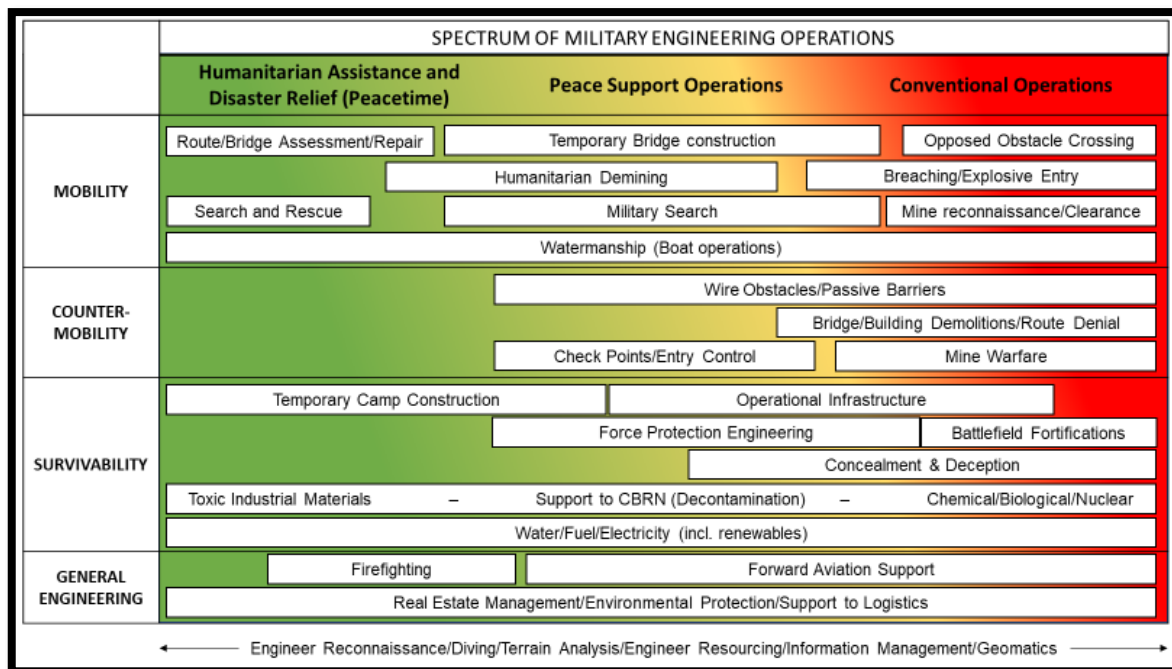


Figure 0-1: The Spectrum of Engineer Operations (Kavanagh, 2023).

Adaptation in Conventional Operations: Ukraine

Russia's invasion and annexation of Crimea in 2014, along with the gradual reduction in COIN operations by Western militaries, has led to a re-focus on peer-on-peer conflict, or Large-Scale Combat Operations (LSCO). With this, the focus of military engineering internationally has returned to dealing with old issues such as wide wet gap crossing and conventional force mobility. Nitschke (2018) asserts that investment is required in military bridges; engineering intelligence; and area denial. It is also argued that in future conflicts, lessons from COIN operations such as C-IED and protected logistics, along with new lessons such as Counter Unmanned Aerial Systems (C-UAS) will be essential to survive on the modern battlefield (Reynolds, 2019). Western nations are looking towards autonomy to remove the military engineer from the danger area. However, innovation competitions such as the UK's "Bridge to Fall!" (Defence and Security Accelerator, 2023), bridge demolition programme, are still very much at the lower levels of technology readiness.

At time of writing (May 2023), Russia's invasion of Ukraine has comprised of an initial Russian offensive on multiple fronts, followed by a Ukrainian counter-offensive in late summer 2022. The winter of 2022/2023 has been marked by largely static, attritional warfare, along entrenched front lines and urban strongpoints. The much-anticipated Ukrainian spring offensive, using recently donated western equipment, has yet to materialise. Although information emanating from the current conflict in Ukraine remains subject to the fog of war, with minimal long-term analysis, it is worth identifying initial lessons from a military engineering perspective from both open-source analysis and initial reports on the crisis. This section will examine these lessons within the areas of counter-mobility, mobility, and survivability.

Lessons in Counter-Mobility

The opening salvos of the war were characterised by Ukraine's successful attempts to disrupt Russia's advances. This involved bridge demolitions, felling trees (*abatis*), and cratering roads, as well as the deliberate flooding of major rivers (Watts and Williams, 2022): all well-worn tactics recognisable to any military engineer. Their effect, when combined with small groups of anti-armour detachments and indirect fires, was decisive in delaying the Russian advance (Zabrotskyi *et al.*, 2022). While later in the war, bridges within enemy territory were destroyed using long-range precision artillery (Reuters, 2022); demolitions out of contact or in the face of the enemy appear to have used traditional methods, with some ad hoc use of mines in lieu of demolition charges.

Mine warfare has been extensive on both sides. Notably, Ukraine is a party to the Ottawa Convention, banning the use of anti-personnel mines whereas Russia is not. While permitted to use anti-vehicle mines, Ukraine has been accused of breaching the convention in the deployment by artillery of anti-personnel PFM-1 mines in the city of Izium while it was held by Russian forces (Human Rights Watch, 2022). While yet unproven, this underlines the continued difficulties in enforcing international humanitarian law when opposing forces are subject to differing rules of war. Some smart munitions have been deployed but the majority have been older mines that are indiscriminate and do not have self-destruction, deactivation, or neutralisation mechanisms (Axe, 2023). These will persist after the conflict creating long-lasting humanitarian harm.

Russia is currently creating large obstacle belts to defend its occupied territories (See Figure 0-2 below). These consist of layers of minefields, ditches, and concrete dragon's teeth in front of

trench networks. It is not yet clear how effective these will be against combined-arms breaching using newly donated western equipment (Ryan, 2023b) although most experts are doubtful.



Figure 0-2: Russian obstacle belts near Sovkhoznoye in occupied Crimea (Africk, 2023).

Lessons in Mobility

The head of engineering in the German Armed Forces estimates that in Central Europe, militaries will meet a water obstacle every 20-30 kilometres that will need to be crossed (Annetzberger, 2023). However, the widely publicised destruction of a Russian river crossing has demonstrated the vulnerability of large-scale river crossings to UAS surveillance, loitering munitions, and long-range fires (Lee and Kofman, 2022). It also emphasises the importance of engineer reconnaissance, which reportedly identified the area as a potential crossing site in advance of the operation (Ulrich and Geiger, 2022). However, this has not been one sided. Ukrainian engineers appear to have accepted this vulnerability and are prepared to replace destroyed bridges on an almost daily basis: “We build them, they blow them up...We’ll rebuild it, and the counteroffensive will resume” (Kostenko in Kramer, 2022). Given the scarcity of these resources, this policy will likely prove to be unsustainable.

A substantial proportion of engineers on both sides, along with NGOs, have been engaged in mine clearance operations using both manual and mechanical means as well as use of dogs (TASS, 2023). This will likely be an enduring legacy of the conflict with claims that about a third of the country is now mined (European Defence Agency (EDA), 2023).

Ryan (2023a), a retired Australian Major General and combat engineer, contends that there has been a large effort to equip Ukrainian combat engineers for their upcoming operations to identify, reduce and move through the dense obstacle zones constructed by the Russian Army in eastern and southern Ukraine. The latest transfers of equipment from the United States include

Armoured Vehicle Launched Bridges (AVLB), mine-clearing equipment, demolitions equipment and munitions for breaching (US DOD, 2023). Similarly, the EDA (2023, p.44) observe that engineering capacities are proving “critical to ensure freedom of movement both for combat operations and in rear areas for operational support”.

Lessons in Survivability

Unacquainted observers may have been surprised at the use of ‘World War One style’ trench systems by both sides. Zabrodskyi *et al.* (2022, p.63) noted that:

The need for hardened cover has been demonstrated throughout this conflict. Shell scrapes and other hasty procedures may improve the survivability of a unit against the opening salvo, but this salvo also risks fixing the unit in cover that is insufficiently protected.

The quality of fortifications varies significantly but demonstrates the continuing need to prepare for conventional defensive operations while also prioritising dispersion and mobility as a key factor in maximising survivability. Commercial drones, adapted to drop explosives, have become a new threat that must now be countered, as must the continued proliferation of thermobaric weapons and persistent satellite surveillance. More scientific approaches to mitigating the blast and penetration effects of weapons, using software design, will be important to adequately protect personnel (NATO, 2016b), even more so in urban operations where existing structures must be hardened. However, these techniques require skilled personnel, qualified and competent to produce such designs.

Summary

So, while much has been made of the ground-breaking expectations of disruptive technology and hybrid actions in modern warfare, the conflict to date in Ukraine has demonstrated that it is premature to abandon tried and trusted tactics, techniques, and procedures. They do however need to adapt to new threats across all domains, which will require innovation and resourcing. The ferocity of the urban battle such as around the city of Bakhmut, point toward the discussion on the future urbanisation of conflict. It is essential that engineers be fully prepared to operate in this environment. Finally, while both sides have used mine warfare to their advantage, the expected long-term damage this will cause should give caution to others and spur on the required innovation for more technologically adept, discriminate alternatives.

Peace Support Operations

Both the CODF (2022) and the UN (Day, n.d.) agree that PSO is becoming more demanding due to the proliferation of weapons as well as the misuse of emerging disruptive technologies, especially in the transfer of IEDs and drones. The physical environments in which PSO take place will also become more extreme due to the impacts of climate change. The publication in 2015 of the UN Military Engineering Unit Manual, and its subsequent revision in 2020 (Office of Military Affairs, 2020) demonstrates the growing requirement for this capability.

Boutellis and Smith (2014) discuss in detail the benefits of military engineering to UN peace operations; however, this publication focuses on the construction role, largely ignoring the combat engineer functions. Nonetheless, there are important lessons arising from it. Their conclusion, that

critical elements of a mission's mandate can become impossible to fulfil without filling key engineering and logistical gaps, is an essential lesson. As is the misconception that civilians can fill military engineering gaps, concurred with by Burbridge (2016). This has proven unworkable in many missions operating in non-permissive environments. They also show that 40-45% of project budgets³ can be saved by using integral military engineers (Boutellis and Smith, 2014, p.4). Finally, their recommendations include the need for a rapid start-up or surge engineering capacity; better integration of engineering requirements into mission planning; adaptation to changing needs throughout the mission; creating partnerships beyond the mission; and building local engineering capacity. These recommendations will be analysed here in relation to two current UN missions in the Sahel region of Africa.

Mali – MINUSMA

The 2020 revision of the UN Engineer Unit Manual acknowledges the growing asymmetric threats to Peace Support Operations (PSO), incorporating “Counter Explosive Threat Search and Detect” as a key capability for all engineer units deploying on PSO. This is a capability that Ireland has developed over 50 years, both at home and on PSO in the Middle East, in the guise of Engineer Specialist Search and Clearance (ESSC). The UN Multidimensional Integrated Stabilisation Mission in Mali (MINUSMA) is one of the most dangerous PSO missions ongoing, with 165 peacekeeping fatalities since it was established in 2013 (Guterres, 2023, p.9). There have been 548 IED attacks resulting in 103 fatalities and 638 wounded (Guterres, 2023, p.9) in addition to many more civilian victims.

The mission's engineer capabilities, consisting of both engineer and EOD companies, are dispersed across its five sectors, with the majority in Sector East and North. The engineer companies are engaged in construction of base camp, as well as the mission's air support infrastructure (United Nations, 2022). EOD Companies conduct both EOD/IEDD as well as route clearance and other military search functions, similar to the role of the Irish ESSC and IEDD teams deployed as part of the Force Reserve Company within the UNDOF mission. The level of intensity of this threat required a new partnership with the UN Mine Action Service (UNMAS) who have expanded their scope of operations in recent years to include IEDs as well as more conventional explosive hazards. In addition to their humanitarian responsibilities, they are responsible for training these companies to the required standards to conduct search and IED Disposal operations with MINUSMA. Critically, in his recent report to the Security Council, the UN Secretary General requested an additional engineer company and two additional EOD companies per sector, in addition to other capabilities (Guterres, 2023). His request highlighted the importance of these force enablers that would “enhance the ability of the Mission to adopt a proactive, robust, flexible and agile posture in all aspects of mandate implementation.”

South Sudan – UNMISS

Whereas MINUSMA provides an example of military engineers adapting to a proliferating asymmetric threat, the UN Mission in South Sudan (UNMISS) provides two examples of how engineers can bring a specialist capability to a mission in a surge capacity. From 2013-2014, a small team of Irish military engineers deployed to South Sudan to support UNMISS and UNMAS in creating a sustainable national capacity for Conventional Munitions Disposal (CMD) within the newly formed country (O'Grady,

³ Based on data compiled by UNOPS from the MINUSTAH mission in Haiti.

2014). Over two, six-month rotations, the detachment conducted several courses for the South Sudanese National Police Service. Although the deteriorating security situation curtailed the completion of this project, it demonstrated the benefits that small teams of military engineers can bring to a mission at minimal expense to the home nation.

On a larger scale, UK military engineers deployed as part of UNMISS from 2016-2020. This comprised of a standalone task force based on an engineer regimental headquarters with enablers including medics, infantry, signals, logistics and intelligence, numbering 300 personnel (Stuart, 2022). Over four years, they provided construction support to the mission, including the construction of base defence infrastructure, two hospitals, as well as upgrading roads and bridges (UK MOD, 2020a). They also engaged in some capacity building, teaching construction skills to the local population. These types of deployments address Boutellis' and Smith's (2014) recommendations, to have surge capabilities that are adaptable to the changing mission situation, without an open-ended commitment of troops to the mission. Ireland has provided surge engineering capabilities on a number of occasions, notably the deployment of an engineer company to construct new positions in South Lebanon following Israel's withdrawal in 2001. Ireland also deployed a surge engineer platoon to improve force protection of positions following UNDOF's withdrawal to the Alpha Side of the Area of Separation at the height of the Syrian Civil War.

Lessons Identified

If current trends continue, it appears that military engineers on PSO will have to deal with multiple evolving challenges, including deterioration of both the climate and security situation. Surges could provide an opportunity to contribute to politically important missions without entering into an extended commitment. However, they require detailed forward planning, made even more difficult when extreme environments must be accounted for. This will require the capabilities to operate amongst growing asymmetric threats as well as an expeditionary mindset. Shields (2009, p.9) believes this requires transformation at the organisational and individual/unit levels, intrinsically linked to core values, so that soldiers are:

Mentally prepared to deploy anywhere in the world on short notice; have the critical-thinking skills to adapt quickly to a rapidly changing operational environment; appreciate and work cooperatively with other members of a Joint team; and possess sufficient knowledge of the culture in the area of operation to be able to interact with the local populace.

Humanitarian Assistance and Disaster Relief Operations

As climate change accelerates, its impact on the developing world will become increasingly acute. Developing regions will be disproportionately affected by climate change and, in many cases, lack the resources to manage the consequences without international support. As recently as February 2023, Turkey and Syria were devastated by a series of massive earthquakes leaving thousands dead and multiples of that homeless, requiring a global response. "Humanitarian operations are not merely an extension of politics but an infusion of social capital" (Greet, 2008, p.61) and are a strategic objective of the Defence Forces (DOD, 2021). UNOCHA (2007) in their 'Oslo Guidelines' on the use of the

military for HADR have described military assets as complementary to existing relief mechanisms, not a primary response mechanism. The UNHCR (1995, Sec.6.5), however, has acknowledged, “the benefit of military engineering elements for humanitarian operations is beyond question. Rarely will humanitarian organizations be in a position to provide similar expertise and resources.”

Military Humanitarian Assistance Doctrine

In his thesis on the subject, McEvoy (2009, p.47) found that without proper coordination and doctrine, militaries “will not have the shared understanding and ‘legitimacy’ to operate successfully in a multi-agency humanitarian environment.” Several examples of military doctrine on this subject exist and could assist Ireland in developing its own.

NATO’s (2022b) Humanitarian Assistance doctrine acknowledges the primacy of civilian agencies. It also provides detailed planning considerations including on the best use of military engineers. It emphasises the need to fully understand the position of other humanitarian actors to enable adequate decision-making and execution of military HADR. It promotes the UN’s ‘Cluster Approach’ to coordinating assistance, where designated humanitarian bodies are responsible for specific response areas. This ensures greater leadership and accountability in sectors where gaps have been identified, as illustrated in Figure 0-3 below. For example, during recent disaster relief efforts in Turkey, Advanced Search teams from the Swedish engineer regiment were deployed to conduct search and rescue operations (Toll, 2023). In this case, their efforts would have been coordinated by the UNDP as the lead agency for the Early Recovery Cluster. Should engineers be deployed to provide potable water, this would be coordinated by UNICEF.

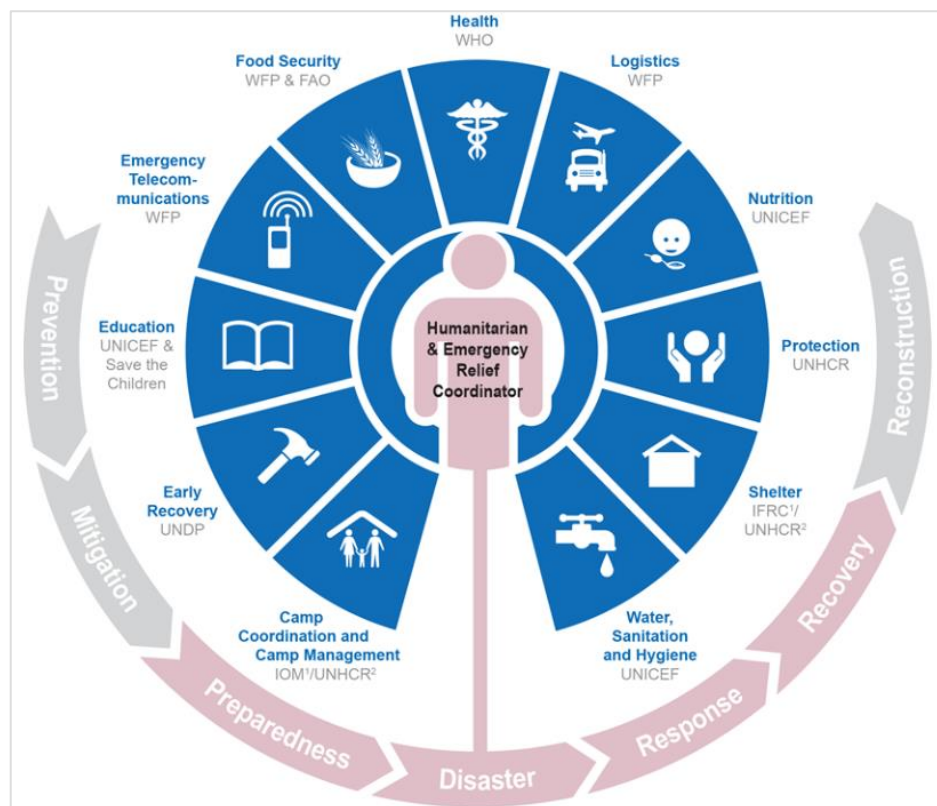


Figure 0-3: Example of a UN Humanitarian Cluster (UNOCHA, 2020)

UK HADR doctrine (UK MOD, 2016) states that military assets are only used when there is an acknowledged gap in capability, defined through an MOU between the UK MOD and the UK's lead agency for humanitarian aid, DFID. It identifies engineer assessment and analysis; and geospatial support as two key capabilities for the assessment and command and control of disaster response. The use of small boats capability is also identified as a potential contribution to support transport, supply, and distribution. It emphasises the importance of liaison, with a chartered engineer officer with infrastructure and operational HADR experience posted permanently at DFID as a liaison officer between both organisations⁴.

Military Engineering in HADR

Military engineers can bring capabilities to the aid of humanitarian organisations such as light and heavy plant machinery; restoration of essential services; construction; water purification; firefighting; small boat operations; and search and rescue, amongst others.

The New Zealand Defence Forces (NZDF) places significant emphasis on HADR within its capstone doctrine (NZDF, 2017a). Within its small engineer regiment, one of its three engineer squadrons is designated as an Emergency Response Squadron, in addition to its combat engineer role, with three platoons dedicated to emergency response. Each engineer squadron is tasked with HADR and civil assistance in New Zealand and in the Southwest Pacific ('2nd Engineer Regiment', 2020). Their utility was demonstrated with the deployment of their firefighter trained engineers to both Australia and Canada to assist in fighting wildfires (NZ Herald, 2018 and Roy and Lyons, 2020).

One operation that demonstrates the utility of a joint force providing complimentary capabilities in a HADR role was the joint operation conducted in 2016 to rebuild and repair services in Fiji following a devastating cyclone (NZDF, 2023a). The operation began with air force transport of an inter-agency Joint Reconnaissance Team, with a military engineer team following, to begin the clean up and to re-establish services such as power and potable water supply. This was followed by the arrival of a 300-strong force of engineers and medics aboard a multi-role vessel within a week of the disaster. At time of writing, New Zealand's military engineers are engaged in HADR operations on their home soil as their construction and combat engineers' clear roads and create novel solutions to cross destroyed bridges in the wake of Cyclone Gabrielle (NZDF, 2023b).

Lessons Identified

In a study by SIPRI (Wiharta *et al.*, 2008), it was recommended that military commanders and forces in countries who may take part in HADR operations should have appropriate doctrine and standard operating procedures, compiled in line with the Oslo Guidelines. McEvoy's (2009) study identified that it was inevitable that the Irish Defence Forces will be involved in HADR and recommended that Ireland should have a comprehensive doctrine on military assistance to HADR, developed in coordination with civilian humanitarian actors and with Irish Aid as the lead. Since 2022, Ireland has been a member of a PESCO project to create a Deployable Military Disaster Relief Capability. The

⁴ DFID merged with the Foreign and Commonwealth Office to form the Foreign, Commonwealth & Development Office (FCDO) in 2020, however this role continues within the new organisation (D Jones, 2023, personal communication, 21 April).

project, led by Italy, aims to develop a disaster relief training centre as well as an EU-wide deployable military disaster relief capability task force (Coveney, 2022). This force could be activated at short notice following a request for assistance and may provide a mechanism to develop this capability.

Conclusion

This part argues that the requirement to maintain pace with the adapting security environment is as important now as in any other time in modern history. Adversaries have taken lessons from recent COIN operations and employed them against peacekeepers, as well as in conventional warfare. The changing climate has exacerbated the operating environment and increased the probability of humanitarian disasters to which the military will be expected to respond.

The war in Ukraine has demonstrated that traditional combat engineering practices remain valid today. Modern military engineers must still be adept at reconnaissance, gap crossing, demolitions, mine warfare, obstacle design and fortifications. However, more comprehensive, scientific methods, learned through recent crisis response operations, can provide better tools to mitigate new threats and challenges, provided personnel are adequately trained in their use. Combined-arms training and integration will remain essential, Russian operations have proven the earlier lesson that “if gap crossing is viewed as an ‘engineer sport’ it was unlikely to be successful in practice” (Watling, 2022, p.4).

The profusion and misuse of disruptive technology has forced militaries to adapt C-IED doctrine for impartial peace support operations. It will require the continued adaptation to threats like UAS to protect peacekeepers in increasingly austere environments. Ireland has an advantage in its long tradition of ESSC operations but will need to adapt further for this deteriorating threat environment. For small military organisations, the surge capability may allow for meaningful contributions to PSO within increasingly constrained resources. HADR operations also provide this “social capital” but require proper preparation to make a meaningful contribution.

These scenarios are representative of the primary roles of the Defence Forces but do Ireland’s military engineers, in their current form, have the capabilities to support operations in light of these emerging challenges? If not, what must be done and how can this be prioritised?

PART THREE. A way forward

“The Sappers really need no tribute from me; their reward lies in the glory of their achievement. The more science intervenes in warfare, the more will be the need for engineers in field armies; in the late war there were never enough Sappers at any time... their contribution to victory was beyond all calculations.”

Field Marshal Bernard Law Montgomery, 1945 (Scott, 2022)

As Montgomery, amongst many other military leaders throughout history remarked, militaries can never have enough engineers, and a time of crisis is generally too late to begin training more. Therefore, as a capability, they must be developed and maintained in peacetime. Having explored

Evolving Challenges in Military Engineering

how modern military engineering has evolved in Part One, and identified emerging threats and challenges in Part Two, this part will analyse where Ireland should go next, in order to meet those challenges. As the Irish Defence Forces embarks on a period of force design and regeneration, this part will identify areas for capability development to allow military engineers to support Ireland's military ambitions efficiently and effectively into the future.

Moving towards the 'Midstream' stages of the CDP (Figure 0-1) (McManus, 2022) outlined earlier, this part will provide a Capability Gap Analysis by first describing Ireland's military engineering structures and assessing current capabilities in relation to those outlined in NATO's joint doctrine (Figure 3-2). The CODF highlights a number of countries, comparable with Ireland. These, along with others referred to in previous parts, will be analysed to identify trends in military engineer organisational structures, which may provide a framework for a future Irish military engineer organisation. Finally, it will highlight several risks should these capability gaps not be closed, based on international best practice.

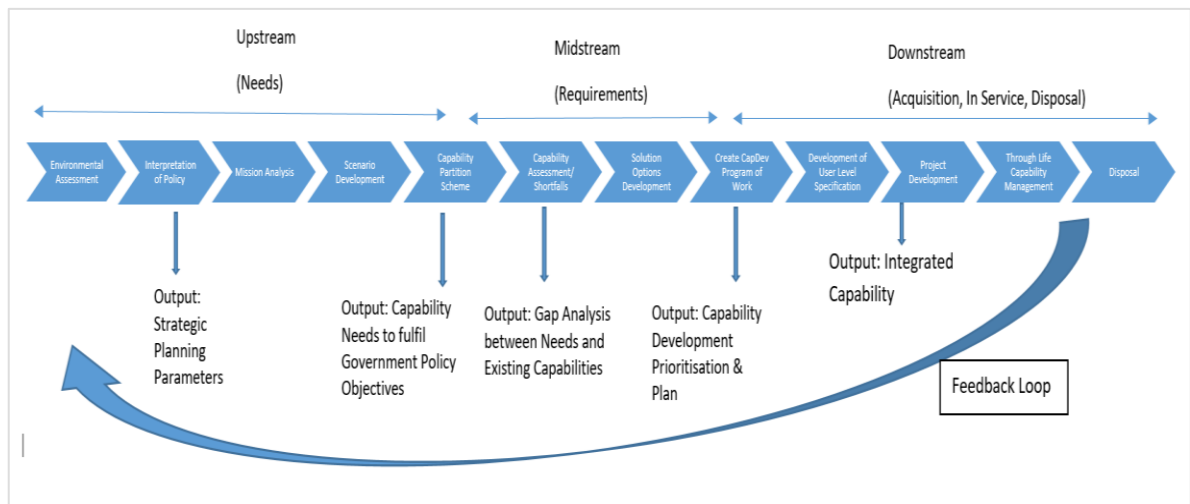


Figure 0-1: Illustrative CDP model (McManus, 2022)

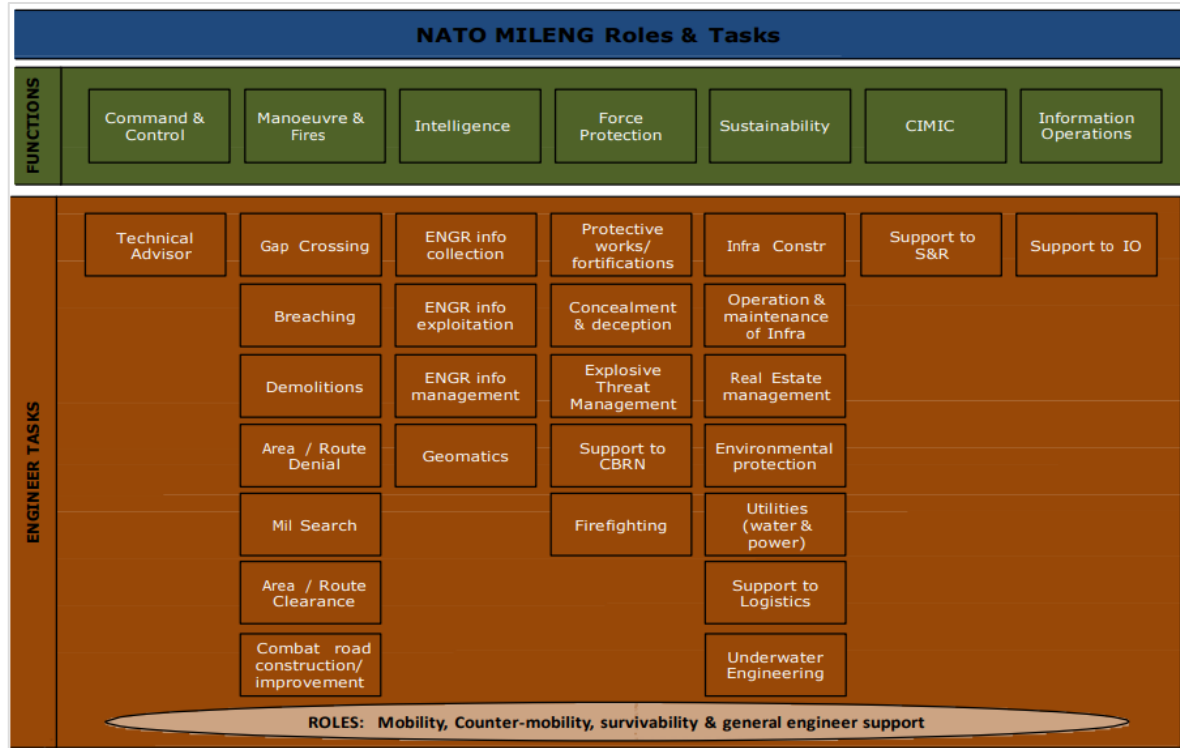


Figure 0-2 Framework of MILENG Roles and Tasks (NATO 2016a)⁵.

Military Engineering in the Irish Defence Forces

The primary provider of military engineering capability within the Irish Defence Forces is the Corps of Engineers (COE). Established on 1 October 1924, it has been comprised of company sized units for the majority of its history. Each operational component of the army, the brigade, contained a Field Engineer Company, with its commander as the Brigade Engineer. The Curragh Command housed the Depot including a training school and the Curragh Fire Station, along with two field engineer platoons (Hardwick, 1985). Army territorial commands controlled a Maintenance Company that was responsible for the upkeep and development of the Defence Forces' built infrastructure. They contained a small cadre of military engineer personnel and a workforce of civilian tradesmen. A small section was also attached to the Ordnance Survey to provide a geomatic capability. With the disestablishment of Commands in the late 1990s, the Command Engineer became the Brigade Engineer but with no command authority over engineer units. The Maintenance Units became part of Logistic Support Battalions but remained as garrison entities, i.e., not deployable. The Ordnance Survey detachment was also disestablished. In 2012, engineer units within the Brigades were amalgamated to form an Engineer Group containing a Field Company of 103 personnel and an Infrastructure and Utilities (I&U) Company (replacing the Maintenance Company) of 23 military personnel, plus civilian staff (Defence Forces, 2015). This unit was commanded by the Brigade Engineer, finally creating a "Single Point of Engineer Advice" at Brigade level, although with a staff of just one corporal in its HQ.

⁵ S&R: Stability and Recovery; IO: Information Operations. CBRN: Chemical, Biological, Radiological & Nuclear

While this paper focuses on the operational elements of the COE, some elements of the wider corps will be discussed where relevant. However, the Field Engineer Companies are the main source of military engineering capability. These have varied significantly in size over time. O'Carroll (2014) notes that during The Emergency, these were normally larger than infantry companies, and at their largest contained 210 personnel (Hardwick, 1985), with their own anti-armour capability for protection of engineer operations. Successive re-organisations reduced this number to a record low of 88 personnel prior to 2012 (Coveney, 2014). They currently consist of two engineer platoons of 34 combat engineer tradesmen and a Support Platoon of 22 plant operators, logistics personnel and drivers. This slight increase is balanced against the disbandment of one company along with the 4th Western Brigade in that re-organisation. Each company also contains one reserve platoon following the disestablishment of the three reserve field companies in 2013.

The two field engineer companies are tasked with providing the full remit of military engineering roles and tasks. In addition to maintaining their individual construction technician competence, engineer personnel are expected to be fully trained combat engineers, ESSC operators, as well as operators of a myriad of specialist engineering machinery from construction plant and generators to remote controlled mine clearance vehicles and reverse osmosis plants. All Irish units deploying overseas contain an engineer element to provide for the survivability of the unit in its bases, as well as its mobility within its Area of Operations.

The Corps has an impressive array of modern equipment including most categories of military bridging, except armoured and floating vehicle bridges; armoured plant machinery; unmanned ground and aerial vehicles for explosive hazard reconnaissance and clearance; remote firing equipment for demolitions; watercraft for inshore troop transport and reconnaissance; CBRN Decontamination systems and a continuously evolving and expanding kit for manual detection and identification of explosive hazards and weapons in all environments. The Defence Forces Training Centre also maintains a full-time fire service. While I&U companies have some Geographic Information Systems (GIS) capability, this is aimed towards infrastructure design as opposed to terrain analysis and mapping.

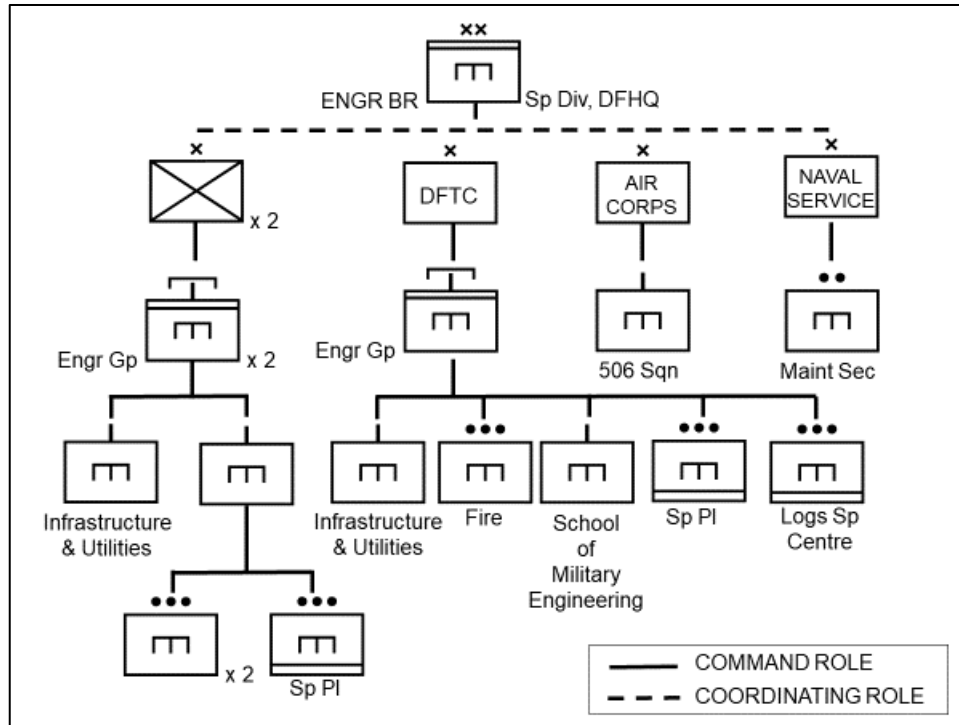


Figure 0-3: Current organisation of the Corps of Engineers (Adapted from Defence Forces (2015)).

International Comparisons

This section describes the quantitative and qualitative analysis conducted to determine similarities or trends in the development of engineer organisation and capabilities in comparable international militaries. The countries selected were chosen due to their similarities to Ireland in terms of their geographic location, population size, military strength, and economic prosperity. There are two outliers from these criteria. The UK was selected as Ireland has traditionally used Royal Engineer doctrine as a basis for its own. They also feature heavily in the case studies in previous parts. New Zealand was selected as it is an island nation with a similarly sized Defence Force, although with several geostrategic differences in terms of defence policy. Data was collected and cross referenced across multiple sources including the Military Balance (IISS, 2023), national military websites, the NATO Military Engineering Centre of Excellence (MILENGCOE), and other sources such as parliamentary questions where necessary. Comparator countries are shown in Table 0-1, with data extracted from IISS (2023).

Country	Population (m)	Defence Spend per capita (USD)	Active Military⁶	Land Component⁷
Ireland	5.3	222	8,200	6,750
<i>Austria</i>	8.9	409	23,300	13,000
<i>Belgium</i>	11.8	478	23,200	8,500
<i>Denmark</i>	5.9	855	15,400	8,000
<i>Netherlands</i>	17.4	875	33,600	15,350
<i>New Zealand</i>	5	664	9,200	4,500
<i>Norway</i>	5.5	1,338	25,400	8,300
<i>Portugal</i>	10.2	253	26,700	13,350
<i>Sweden</i>	10.5	770	14,600	6,850
UK	67.8	1,033	150,350	83,450

Table 0-1: Comparator countries selected. Data: IISS (2023).

Quantitative Analysis

Internationally, there is no standard organisational structure for engineer units, but all nations researched have formed engineer regiments. Many also have smaller units that specialise in certain capabilities such as EOD, infrastructure design, CBRN, amphibious bridging, etc. These often fall outside the regimental structures or exist in echelons above brigade. In order to form a level of equivalence for comparison purposes, this analysis focused on operational (field) units only. Units were divided into ‘company sized equivalents.’ The number of ‘company equivalent’ units in relation to the number of brigade level formations was then analysed to determine the average ratio of engineer companies per manoeuvre brigade⁸. The actual strength of engineer personnel in operational units was then analysed in order to identify a correlation and an international trend in the percentage of military engineers in operational formations. The results are shown in Figure 3-4 and Figure 3-5, below. Only regular units were included in this analysis.

⁶ Actual strength of Armed Forces according to The Military Balance (IISS 2023)

⁷ Actual strength of Land Component according to The Military Balance (IISS 2023)

⁸ In this case a manoeuvre brigade represents Armoured, Infantry or Combined Arms Brigades.

Evolving Challenges in Military Engineering

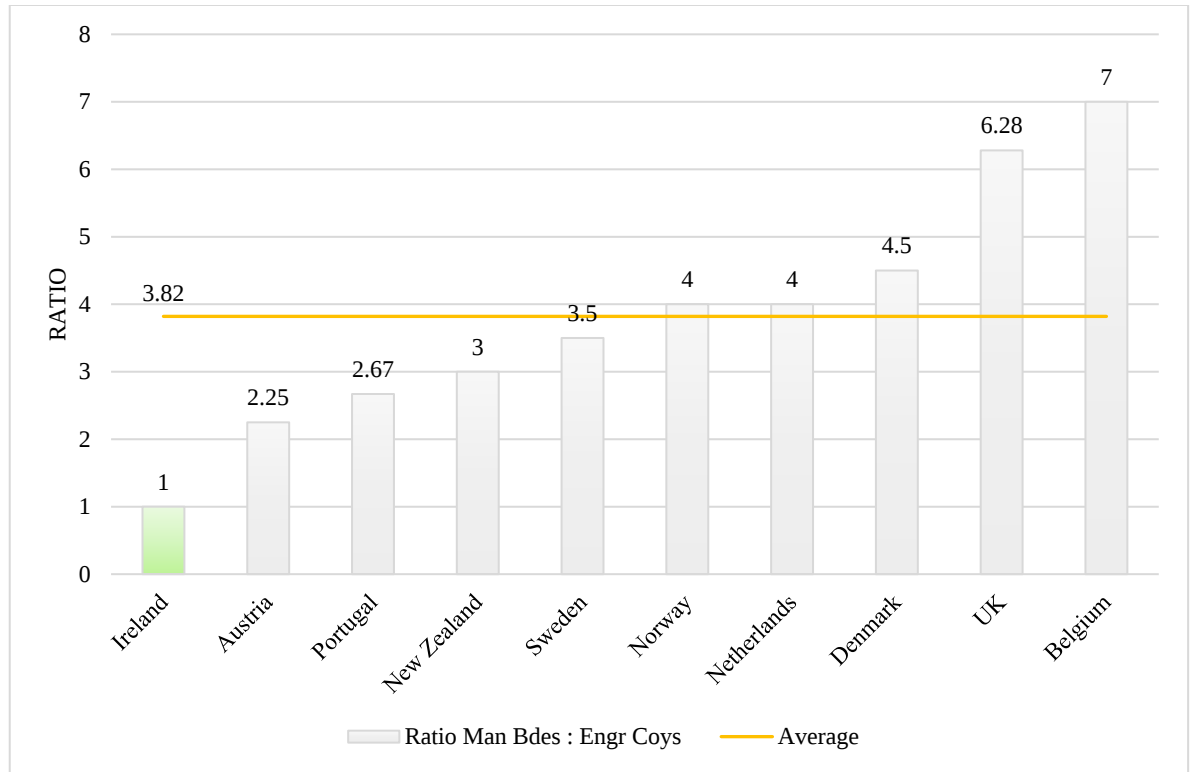


Figure 0-4: Engineer Units (Company Equivalent) as a ratio of Manoeuvre Brigades within the Land Component.

Figure 3-4 clearly shows that Ireland is an outlier with its low number of engineer units within the Army. On average there are almost four (3.82) field engineer companies for every manoeuvre brigade. It can also be seen that Belgium and the UK are outliers with their heavy weighting of engineer units. When these three outliers are removed, the average ratio of manoeuvre brigades to engineer companies is reduced to 1:3.42 – roughly equivalent to a battalion/regiment in size for each brigade with a smaller unit in the echelon above.

Evolving Challenges in Military Engineering

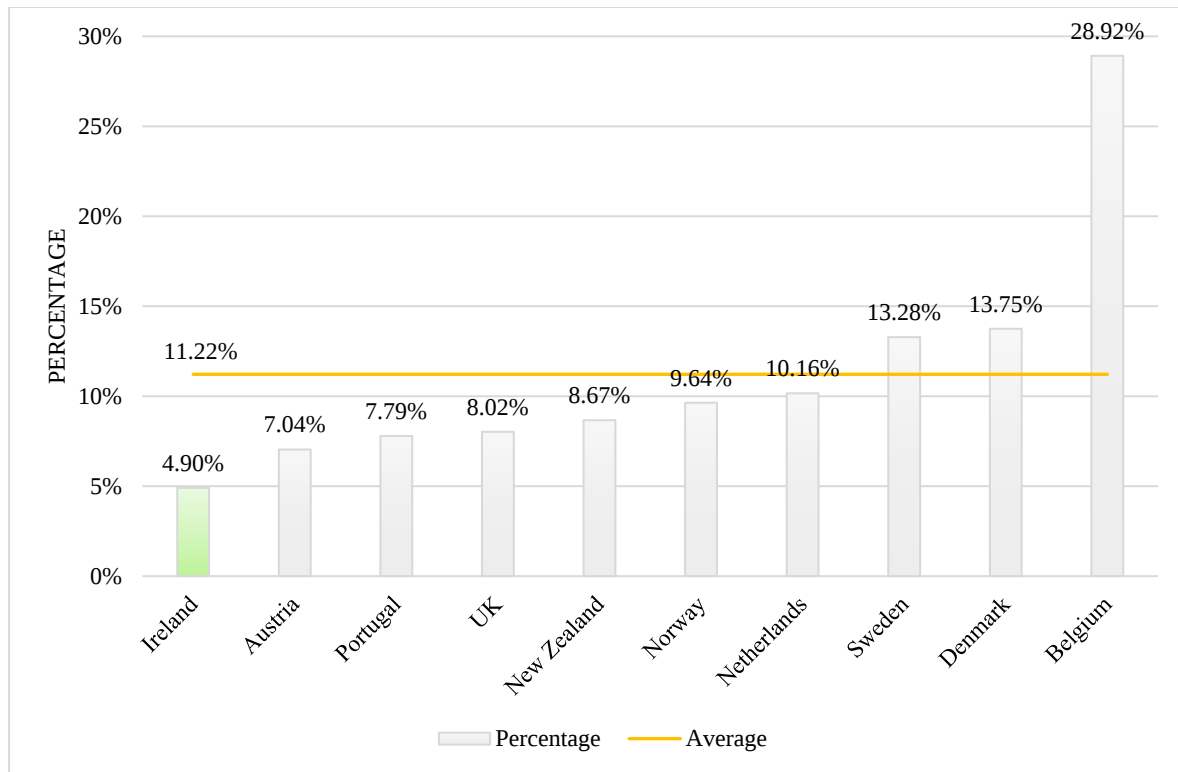


Figure 0-5: Engineer personnel as a percentage of the Land Component.

Figure 3-5 shows a similar trend. Ireland has 56% fewer military engineers as part of its operational forces than the average of comparator countries. When outliers Belgium and Ireland are removed, the average is reduced from 11.2% to 9.8%, meaning Ireland still has only half the number of engineers compared to the international average.

It is important to note that when compiling data, it was not always possible to obtain exact figures of countries' unit strengths, due to operational security amongst other reasons. Where exact figures were unavailable, data was limited to operational units only, so in Ireland's case, although the established strength of the COE is 370 (Defence Forces, 2015), a figure of 331 was used which excludes Engineer Branch, DFHQ and the School of Military Engineering. The true establishment of the COE in operational units is actually 225 personnel and the actual strength is less again, however other elements regularly reinforce field companies on operations/exercises, so the higher number was assessed as more suitable. Other variations found were the inclusion of EOD and CBRN units as part of engineer regiments in many cases but constituting a separate corps in others. A full breakdown of data compiled is shown in Appendix A.

This purely quantitative analysis indicates that Ireland would need to, at a minimum, double the strength of its military engineers in order to meet similar capabilities.

Qualitative Analysis

Based on these findings, three countries were selected for a deeper, qualitative analysis. New Zealand is similar in the strength of its armed forces, although its land component is smaller than

Ireland's. Belgium provides a European example of a small European military that has a strong military engineering capability. Finally, although a significantly larger force, structures in the UK warrant close examination as they may provide scalable solutions for Ireland's capability gaps.

Country	Belgium	Ireland	New Zealand	UK
Active	23,200	8,200	9,200	150,350
Reserve	5,900	1,600	3,010	71,950
Land	8,500	6,750	4,500	83,450
Operational Engrs⁹	2,548	331	390	6,696
Manoeuvre Units	1 x Mech Bde	2 x Light Inf Bde	1 x Inf Bde	1 x STA Bde 2 x Armd Bde 1 x Inf Bde 1 x Mech Inf Bde 1 x Air Asslt Bde 1 x Cdo Bde
Operational Engr Units (Regular force)	2 x Multirole Engr Bn 1 x EOD Gp 1 x Paracommando Engr Pl 1 x Field Accommodation Unit	2 x Fd Engr Coy 1 x Fd Sp Pl (-) 1 x Fire Fighting Pl	1 x Engr Regt	3 x Gen Sp Engr Regt 4 x Close Sp Engr Regt 2 x EOD/Search Regt 1 x Para Engr Regt 1 x Cdo Engr Regt 1 x Geo Engr Regt 1 x Amphib Sqn (within Joint Ger-UK Engr Bn) 1 x Infra Sp Gp

Table 0-2: Engineer structures of selected countries.

New Zealand

The Royal New Zealand Engineers (RNZE) operated as independent squadrons until they were formed into 2nd Engineer Regiment in 1993 (McGibbon, 2002). This unit contains two Combat Engineer Squadrons (one of which is also designated as Emergency Response), with integrated reserve platoons, and one Force Support Engineer Squadron. The latter contains two construction platoons and one plant platoon. Each combat engineer squadron is designated to support one of New Zealand's two regular infantry battalions along with its one cavalry regiment, with integrated reserve platoons supporting reserve battalions.

The unit provides similar capabilities to that of the Irish COE with the addition of Explosive Detection Dogs (EDD) for Military Search, a diving capability, and an extensive capability for "resource winning" i.e., mobile sawmills and rock crushing. This is likely a requirement due to New Zealand's specific environmental conditions. The main difference is the existence of a single headquarters that can provide command and control as well as centralised project management and logistics support, allowing for the engineering principle of "Centralised Control, Decentralised Execution". Additionally,

⁹ Includes engineers in operational units (companies, battalions, regiments, etc.). Excludes engineers in headquarters and training establishments.

the Force Support Squadron creates a pool of construction specialists that can provide specialised support for HADR and civil emergency support. They also integrate with Defence Estate and Infrastructure projects to supplement delivery while enhancing trade-training (NZDF, 2020).

The NZDF is currently undergoing a force design process in tandem with a Defence Policy review which prioritises the challenges of China and climate change over homeland defence, using a more threat-based approach to planning (Fish, 2022). In its Future Land Operating Concept (NZDF, 2017b), the engineer regiment is highlighted as a unit with a diverse range of equipment assets that would normally be held at divisional level in other forces – an issue in common with Ireland. The concept specifies the key development priorities for engineers as: Urban Operations; Green and brown water operations; increasing engineering capacity across the force; and a potential increase in contribution to Civil-Military Coordination (CIMIC) operations. A new force design for RNZE is due to be published in 2023.

Belgium

Belgian engineers are organised into two engineer battalions within their one large Motorised Brigade of 7,500 soldiers. An EOD Group and Field Accommodation Unit (FAU) under the Chief Engineer also lie within the Land Component but support all components of La Défense. There is also a platoon of “paracommando engineers” within the Special Operations Regiment (NATO MILENGCOE, 2023). This platoon provides an Advanced Search, EOD, and breaching squad; a boat squad; and an amphibious recce squad with dive teams. Each engineer battalion of approximately 600 soldiers (Defensie, 2020) and is made up of two combat engineer companies; and one general engineer company.

Each battalion has two mechanised combat engineer companies containing its assault bridging, route clearance, EOD and EDD capabilities. The general support company contains a CBRN Platoon with collection, sampling, identification, and decontamination capabilities; an Advanced Search Platoon including divers; and two construction platoons. Similar to New Zealand, Belgium has included the full remit of engineer tasks within the brigade but with more resources and greater delineation of capabilities within its subunits. It also works closely with French and Dutch engineer units to maintain these capabilities. EOD capability was transferred from Logistics to Engineers in 2011 and contains about 300 personnel, largely devoted to clearance of UXOs from both world wars, dealing with about 3000 devices per year (BeEODA, 2023). The Field Accommodation Unit specialises in force infrastructure support to deployed operations, including accommodation, power supply, force protection equipment and medical infrastructure.

The Belgian Defence Forces are beginning an expansion as part of the new strategic vision, the STAR (Security, Technology, Ambition, Resilience) plan, which aims to increase the size of the armed forces by 5,000 personnel to 30,000 by 2030 (Biscop, 2022). It will also increase equipment procurement, including for engineers, who had to rent bridges as part of their response to widespread flooding in Belgium in 2021 (Koutouzi, 2022). Belgian AEVs are also in the process of being replaced with JCB’s HMEE, also used by Ireland, as part of its modernisation, replacing its tracked armoured engineer vehicle (Fiorenza, 2021).

United Kingdom

In its last reorganisation, the UK's Royal Engineer's (RE) close support regiments were grouped within its warfighting division under 25 Close Support Engineer Group (excluding a Commando and a Parachute Engineer Regiment which sit with 3 Commando Brigade and 16 Air Assault Brigade respectively). Force Support units are under 8 Force Engineer Brigade which controls the General Support Regiments; an EOD group containing both RE and Royal Logistics Corps 'EOD and Search' Regiments and a Military Working Dog Regiment; and an Infrastructure Support Group. The latter is organised into Works Groups containing STRE. Each STRE specialises in design and construction of either air support, water, fuel, power, force protection, camp, port, or rail infrastructure. They are staffed by chartered engineer officers and senior NCO Clerks of Works. Approximately 34% of STREs are Reserve units. STREs provide specialist design advice which can then be passed on to regular RE units who provide the construction force. The RE also has a Geographic Regiment capable of providing survey, mapping and terrain analysis, and an Amphibious Squadron that is part of a joint British-German Engineer Battalion in Germany (UK MOD, 2020b).

Most regiments consist of three field or armoured squadrons and a Support Squadron, equating to between 600-700 troops (Lancaster, 2018). Of interest is the Support Squadron which contains a Reconnaissance Troop; a Support Troop holding plant and bridging assets; a logistics section including integral heavy lift of engineer resources; and a Construction Supervision Cell (UK MOD, 2008). The latter is commanded by a Chartered Engineer and provides 'in-house' planning and management of smaller infrastructure tasks and a conduit to the STREs. While Ireland has two field engineer units, it has no corresponding structure to provide these types of supports.

Summary

This analysis indicates that Ireland has a disproportionately small military engineering organisation compared to those selected. While there is no standard organisation, the regimental structure has been adopted by all. It is also uncommon for company sized units to be tasked with the full remit of military engineering capabilities, instead most have divided into close and general/force support tasks with CBRN being included in the latter. New Zealand is the only country analysed that have a firefighting capability other than Ireland.

However, it is also clear that even relatively large forces such as the UK are unable to maintain the full range of capabilities without partnerships with allies. There are several variations of how infrastructure support can be integrated into regimental structures, with STREs, particularly reserve STREs, providing a potential solution to developing specialisms required for overseas deployments. Ireland is the only country that does not have an EDD capability.

Capability Gap Analysis

New capabilities require effort across all lines of development (DOTMLPFI – Figure 3-6). Recalling the CDPP model illustrated in Figure 3-1, the 'Midstream' stage is designed to assess future requirements by outlining current capabilities, specifying a desired end state, articulating risks, and developing prioritised corrective actions through the Capability Development Program of Work to address any gaps identified (Figure 3-7).

Evolving Challenges in Military Engineering

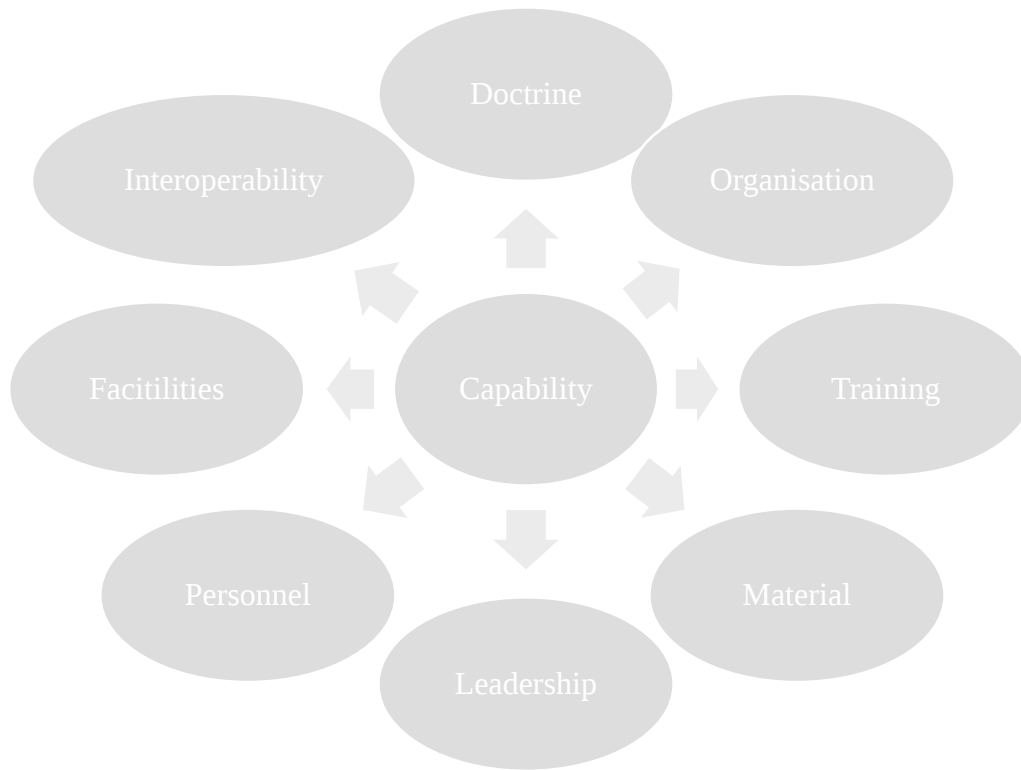


Figure 0-6: Defence Lines of Development (DLOD) required to support capabilities (adapted from Ó'Murchú, 2022),

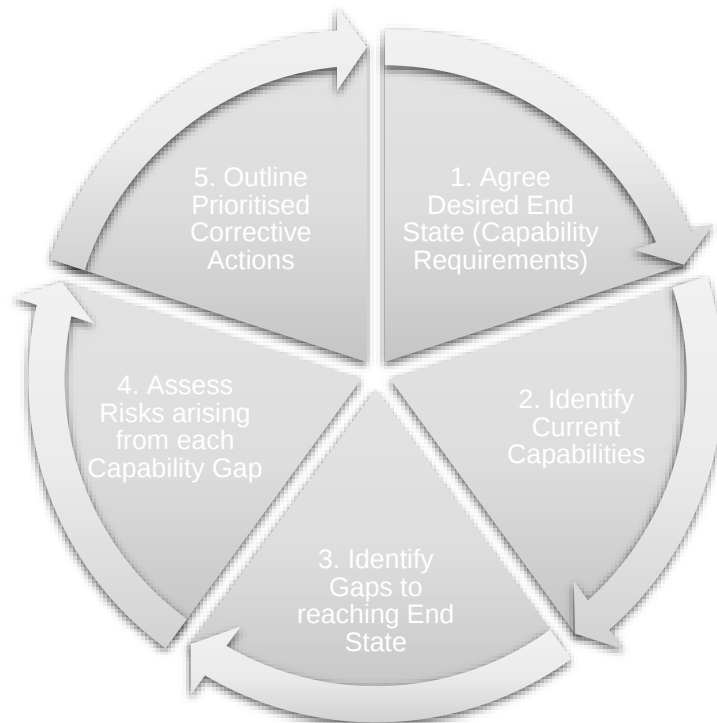


Figure 0-7: Illustrative model for Capability Gap Analysis

1.1.1 Desired End State

Interpreting Defence Policy as laid out in the Defence White Paper (DOD, 2019) and the HLAP (DOD, 2022), a potential desired end state for military engineering in the Irish Defence Forces would be:

A modern Military Engineering force capable of providing Mobility, Counter-Mobility, Survivability, and General Engineering support for conventional defence of the State against armed aggression; robust Peace Support Operations in increasingly austere, high-threat environments; and Humanitarian Assistance operations at home and abroad.

Current Capabilities and Gaps Identified

Ireland's current capability is outlined at the start of this part, with capability gaps in comparison to other similar nations discussed above. Part One and Two also highlight areas that require capability development. These are summarised in Table 0-3 below along with emphasis on the priority lines of development to achieve each:

<i>Paper Reference</i>	<i>Areas identified for Capability Development</i>	<i>Priority DLODs</i>
Part One - Iraq 2003 -Afghanistan	Joint Force Engineer Capability.	Doctrine; Organisation; Leadership
	Single Point of Engineer Advice at all levels.	Organisation; Leadership
	Continued development of ESSC including EDD capabilities.	Training; Material; Organisation
	FPE detailed design and construction.	Organisation; Training; Personnel
	Dismounted Close Support Engineering.	Training; Material
	Gap Crossing in a contested asymmetric environment.	Training
	First Principle's Design capability.	Training
Part Two - Ukraine -PSO/HADR	Increased survivability against UAS and other disruptive technologies in Multi-Domain Operations.	Doctrine; Material; Training
	Technological substitution for mine warfare.	DOTMLPFI (all)
	Development of engineer TTPs in urban operations.	Training; Leadership
	Adaptation of COIN based FPE techniques for conventional operations.	Training; Material
	Surge capacity to respond to short duration PSO and HADR operations.	Organisation; Personnel
	Doctrine and TTPs for deployment on HADR.	Doctrine; Training
Part Three - International Comparisons	Rebalancing/reorganisation of forces to reach adequate levels of engineers within the land component.	DOTMLPFI (all)
	Delineated unit responsibilities for specific military engineer tasks.	Doctrine; Organisation;
	Use of specialist reservists to increase professional engineering capacity in specialist areas (Specialist Teams).	Organisation; Personnel; Training

Table 0-3: Capability Requirements identified.

Risk

The capability gaps highlighted above vary significantly in terms of the challenges posed in addressing them. While some represent an ongoing requirement to maintain pace with international developments and standards, others will require a fundamental change in organisation and culture. The former can be addressed through prioritisation of training efforts. The latter will require a more long-term focus, balanced against competing demands for resources. However, it has been clearly shown that it is not possible to maintain the full spectrum of engineer capabilities required to support future Defence Forces operations without a properly balanced and organised force, one that leverages all resources available to it, including reserves.

Failure to address these capability gaps could ultimately put future ambitions to deploy on more robust PSO at risk. While on deployment, failure to adapt to evolving threats, and an inability to deploy sufficient combat support troops, ultimately increases risk of harm to our soldiers, both engineers and others. However, mitigating these risks presents new opportunities for both the Defence Forces and Ireland. The specialist reserve is a concept that has not developed and utilisation of professional, civilian, engineers to provide specific design solutions to engineering problems could be a key enabler for the Defence Forces. A larger and more capable engineer corps also creates wider opportunities for the Defence Forces to deploy overseas, outside of the traditional infantry focused operations.

Conclusion

Considering the overarching question of this paper: “how can small military organisations meet the growing need for military engineering capabilities”, this part synthesises lessons identified throughout, and uses the CDPP model to identify areas requiring capability development. This has produced a substantial list of capability gaps that constitutes a significant program of work outside the scope of this paper. However, the main conclusion is that Ireland has been ‘punching above its weight’ in the field of military engineering. As technology develops and standards increase, it is doubtful whether such a proportionately small corps can continue to meet its requirements to support Defence Forces operations. Although rectifying this may involve a cultural shift in our military organisation, it is necessary in order to create a modern balanced force, fit for the 21st Century security environment. In concluding this research, it should be highlighted that, while it may be possible to prioritise or relegate some military engineering capabilities such as armoured or amphibious bridging, doing so should be done with the full acceptance of the risks in terms of overall defence capability, as well as the risk to our deployed soldiers and those we protect.

CONCLUSIONS

"Good engineers are so scarce, that one must bear with their humours and forgive them because we cannot be without them"

Lord Galway, Massue de Ruvigny, 1704 (Royle, 2021)

This paper set out to answer the question "How can a small military organisation such as Ireland's, meet the growing need for military engineering capabilities as they evolve in line with military operations and technological advancement?" In doing so, it has examined a number of operational scenarios, from conventional warfare to counterinsurgency as well as peace support and humanitarian operations. These align broadly with the primary roles of the Defence Forces as set out by government. It then synthesised the lessons identified and assessed Ireland's military engineering capabilities in relation to comparator countries.

The research has shown that there is a clear benefit to maintaining a robust military engineering capability. While the Defence Forces has managed to keep abreast of developing concepts, it has failed to adapt its organisation and doctrine in line with international best practice over the preceding decades, at least from a military engineering perspective. In doing so, the ratio of forces within the land component has become more unbalanced and unsuitable for modern operations without significant external support. Further adaptation is now needed to mitigate new threats from emerging disruptive technologies while also playing catchup with international standards.

The analysis recognised that all comparator militaries have had to make choices in relation to prioritisation of military engineering capabilities. Very few are capable of providing a full capability in all military engineering roles and tasks, with the majority engaged in some level of partnership to bridge that gap. This course of action is more challenging for neutral Ireland. Multi-role engineer battalions/regiments such as New Zealand's or Belgium's appear to be the best fit for smaller nations, however all have delineated areas of responsibility at company level if not battalion. This allows personnel the bandwidth to develop competence in their area of expertise, whether that be close support engineering, infrastructure support, CBRN, Military Search or EOD. Integrated units of reserves and regular soldiers were less common but, in most cases, reserves have been given specified responsibilities. For example, the UK's wide wet gap crossing capability is provided by one reserve engineer troop based in Germany and collocated with a German amphibious engineer regiment. Similarly, some of its more specialist STRE are made up of reservists, for example its railway engineering specialists based in Northern Ireland.

Recommendations

As with all areas of capability, prioritisation is key for small military organisations. Options available to provide capability include developing it within the Permanent Defence Force, relegating certain capabilities to the reserve, or seeking external support, either from partner nations or civilian contract. Each of these options come with a cost, financially or otherwise.

Reliance on the reserve may limit the scope of deployment of certain capabilities, for example, those regularly required on peace support operations. However, the reserve could provide a pool of potentially untapped experience from industry that could be beneficial in areas with significant crossover such as infrastructure design, provision of utilities, or GIS capabilities. The Specialist Reserve is a concept first mentioned in the 2015 White Paper on Defence (DOD, 2015) but is, as yet, undeveloped. Creation of reservist 'Specialist Engineer Teams' similar to STREs could bolster Ireland's Force Support Engineering capabilities.

The case studies on COIN operations in Afghanistan and PSO operations warned against over reliance on civilian contract for engineer capability. While useful to fill gaps in more permissive environments, they become cost prohibitive or unavailable in more dynamic situations where military options are unavoidable. They could also lead to a degradation of military expertise in those areas, leading to an underdeveloped capability when it is required. For example, while only briefly discussed in this paper, Ireland's ability to maintain and develop its own garrison infrastructure allows its engineers maintain their competence in this important area. Should this be outsourced, it could result in the loss of capability to design and construct the necessary force infrastructure on deployments.

Finally, maintaining military engineering capability within the permanent force will require an expansion above current personnel levels, or direction on what capabilities are deemed non-essential and can be phased out. While it may be tempting to discontinue purely conventional capabilities in favour of those only used on PSO, one must recall Dag Hammarskjöld's paradox – "Peacekeeping is not a job for soldiers, but only soldiers can do it" (quoted in Department of the Army, 1994, p.1). Almost all military engineering conventional skills are transferable to the peacekeeping environment and so there would likely be second order consequences to that course of action. For example, engineering expertise in explosives and mine warfare is the main rationale for their suitability to conduct advanced military search. Certain capabilities could be reviewed. As a purely light or mechanised force, Ireland currently does not require an armoured engineer capability, although it does require mechanised engineers. Most nations appear to have relegated their wide wet gap crossing capabilities to a lower level of priority, although increasingly frequent climate emergencies may force change here. Similarly, of those countries analysed, only Ireland and New Zealand maintain a firefighting capability. Hard choices must be made and should be based on realistic budgets as well as prioritisation based on sound policy guidance.

Organisationally, future force generation plans should factor in the requirement to maintain engineer units at regimental/battalion level in line with best practice and should include appropriate engineer planning staffs at appropriate levels of command in line with the Joint Force Engineering Concept.

Implications of this Research

One of the initial actions in the implementation of the CODY recommendations was the establishment of a Capability Development Planning Process (CDPP). While this should be driven by a top-down approach to capability planning, the concept acknowledges that there is still a need for subject matter experts to provide advice, especially at the Mission Analysis stage, where specialist capabilities need to be considered.

Initial research into this area identified a significant lacuna in the absence of peer reviewed research covering the breadth of military engineering capabilities. It is intended that this piece will begin to close that gap in the research. In doing so it reveals the significant span of military engineering responsibilities that can be overlooked when narrower capability areas are analysed. As the Irish Defence Forces commences a force design process that is likely to transform the organisation and make it fit for the twenty-first century, this research can assist in the process of identifying the most suitable organisation of military engineering forces needed to build and sustain the necessary capabilities at the required levels of readiness.

Further research

While this study focused primarily on the combat engineering roles, further research could take this one step further and examine the civil engineering roles in relation to provision and maintenance of defence real estate on-island. As briefly mentioned above, this responsibility provides the Defence Forces with an opportunity to maintain a capability that can then be employed on operations. However, it is acknowledged that many militaries globally have relinquished this role to civilian contract or public private partnership, and it is worth analysing the benefits and risks of such a decision.

The role of the reserve in the provision of specific capabilities is another area that warrants deeper examination. Ireland's single force concept envisages a reserve that is integrated with the permanent force and can match them in terms of capability. Other nations appear to take a different approach as discussed above and, again, this is an area that could provide interesting solutions to the capability conundrum.

Final Reflection

This research was concluded in April 2023. Ukraine launched its counter-offensive in June. Their objective was to recapture lost territory and close the land bridge to Crimea, but they failed to achieve a significant breakthrough. One of the major reasons for the lack of progress was due to the extent of Russian field defences, with obstacle belts including large swathes of minefields in depth, compounded by insufficient breaching assets on the part of the Ukrainians. Despite the current deadlock, it has again demonstrated the decisive role of military engineering in combat operations and as Ukraine is now considered to be one of the most densely mined countries in the world, there will be an enduring requirement for this skillset once hostilities cease.

As a capability, Military Engineering is a force multiplier: one that must be maintained for war, but one that brings options that can be used in a multitude of crises at home and abroad, in support of Ireland's domestic and global objectives. It is a true 'Swiss Army Knife' of military forces and hopefully one that will continue to grow and develop in response to evolving challenges in the years ahead.

Please note that this views expressed in this article are those of the author alone and should not be taken to represent the views of the Irish Defence Forces, the Command and Staff School or any other group or organisation.

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APPENDIX A – DATA ANALYSIS OF COMPARATOR COUNTRIES’ MILITARY ENGINEERING ASSETS

Table A-1: Comparator countries selected. Data: IISS (2023).

Country	Population (m)	Defence Spend per capita (USD)	Active Military¹⁰	Land Component¹¹
Ireland	5.3	222	8,200	6,750
<i>Austria</i>	8.9	409	23,300	13,000
<i>Belgium</i>	11.8	478	23,200	8,500
<i>Denmark</i>	5.9	855	15,400	8,000
<i>Netherlands</i>	17.4	875	33,600	15,350
<i>New Zealand</i>	5	664	9,200	4,500
<i>Norway</i>	5.5	1,338	25,400	8,300
<i>Portugal</i>	10.2	253	26,700	13,350
<i>Sweden</i>	10.5	770	14,600	6,850
<i>UK</i>	67.8	1,033	150,350	83,450

¹⁰ Actual strength of Armed Forces according to The Military Balance (IISS 2023)

¹¹ Actual strength of Land Component according to The Military Balance (IISS 2023)

Evolving Challenges in Military Engineering

Table A-2: Comparator Countries Military Engineering Assets (IISS 2023)

Country	Land Forces	Regular Manoeuvre Units	Engr Units	Engr Units (Coy equivalent)	Ratio – Engr Coys to Bdes	Engr Vehicles	CBRN Vehicles
<i>Austria</i>	13,000	4 x Bde (Arm, Mech, Light, Mtn)	3 x Cbt Engr Bn	9	2.25	27 x 4KH7FA-SB Greif (11 in storage)	12 x Dingo 2 AC NBC
<i>Belgium</i>	8,500	1 x Mech Bde	2 x Engr Bn, 1 x EOD unit 1 x Field Accommodation Unit	7	7	6 x Pionierpanzer 2 x Dachs; 8 x Piranha III-C, 4 x Leguan AVLB	N/A
<i>Denmark</i>	8,000	2 x Mech Bde	1 x Cbt Engr Bn, 1 x CBRN/Constr Bn, 1 x EOD Bn	9	4.5	3 x Wisent AEV, 6 x BRP-1 Biber AVLB	N/A
<i>Finland</i>	13,400	1 x Arm Regt, 2 x Mech Bde, 9 x Light Bde	7 x Engr Regt			5 x Dachs AEV, 12 x BLG-60M2; 10 x Leopard 2L AVLB; 9 x SISU Leguan AVLB, Aardvark Mk 2; KMT T-55; 6 x Leopard 2R CEV; RA-140 DS	N/A
<i>Ireland</i>	6,750	2 x Inf Bde	2 x Fd Engr Coy	2	1	Nil	Nil
<i>Netherlands</i>	15,350	2 x Mech Bde, 1 x Air Mobile Bde	3 x Engr Bn, 1 x Engr Coy, 2 x EOD Coy, (1 x CBRN Coy)	12	4	Dachs; 10 x Kodiak, 16 x Leopard 1 with Legaun; 2 x Leopard 2 with Leguan; 4 x MLC70 with Leguan, Bozena mineflail	6 x TPz-1 Fuchs NBC
<i>New Zealand</i>	4,500	1 x Inf Bde	1 x Engr Regt	3	3	7 x NZLAV AEV	N/A

Evolving Challenges in Military Engineering

<i>Norway</i>	8300 (3,900 regular)	1 x Arm Inf Bde	1 x Engr Bn, 1 x EOD PI (Navy)	4	4	20 x CV90 STING; 8 x M113 AEV; NM109; 6 x Wisent-2; 26 x Leguan; 1 x Leopard 2 with Leguan; 9 x Leopard 1; 9 x Hydrema 910 MCV-2	6 TPz-1 Fuchs NBC
<i>Portugal</i>	13,350	1 x Mech Bde, 1 x Intervention Bde, 1 x Air Man Bde	3 x Engr Coy; 1 x Engr Bn (Cbt, Constr, EOD, Bridging, CBRN Coys)	8	2.67	M728 AEV, M48 AVLB	N/A
<i>Sweden</i>	6,850	2 x Bde TFs	2 x Engr Bn, 1 x CBRN Coy	7	3.5	6 x Pionierpanzer-3 Kodiak (Ingbv 120) AEV; 3 x Brobv 120 AVLB; Aardvark Mk2; 33 x Area Clearing System	N/A
<i>UK</i>	83,450	1 x STA Bde, 2 x Armd Bde, 1 x Inf Bde, 1 x Mech Inf, 1 x Air Asslt Bde, 1 x Cdo Bde	5 x Engr Regt; 1 x Engr Bde: 1 x CBRN, 2 x EOD, 1 x MWD, 1 x Engr, 1 Air Sp Engr, 1 x Log Regt (Infra Gp), 1 x Geo Engr Regt, 1 x Engr Bn (-) (Joint Ger-UK), 1 x Cde Engr Regt	44	6.28	56 Terrier CET; 32 Trojan AEV; 64 Aardvark; 35 M3 Ferry; 33 Titan AVLB	TPz-1 Fuchs NBC
Average Ratio, Engr Coys to Manoeuvre Bdes: 3.82:1							

Evolving Challenges in Military Engineering

Table A-3: Percentage of military engineers within land components.

Country	Land Component	Engr Forces	Percentage of Land Comp	Sources	Remarks	MILENG COE Data
<i>Austria</i>	13,000	915	7.04%	(Kraker 2021) (Austria MOD 2023)	The level of ambition for crisis response is to be able to deploy and sustain a minimum (on average) of 1,100 troops.	NA
<i>Belgium</i>	8,500	2,458	28.92%	MILENGCOE (BeEODA 2023) (Defensie 2020)	EOD Group, FAU under command of Chief Engineer and his MILENG Staff. Provides sp to all components and Service.	Mil Force: 25,000; Engr Fce: 2,458 - 9.8%
<i>Denmark</i>	8,000	1,100	13.75%	MILENGCOE		Mil Force: 20,000; Engr Force: 1,100 = 5.5%
<i>Finland</i>	13,400	N/A	N/A	N/A	Difficult to discern between regulars/conscripts/reserves.	N/A
<i>Ireland</i>	6,750	331	4.90%	Admin Instr CS4	Total Engr establishment, 370/7520=4.92%	NA
<i>Netherlands</i>	15,350	1,560	10.16%	Military Balance	CBRN Coy as part of one Engr Bn Est. 12 Coys ~ 130pax = 1,560	Nil
<i>New Zealand</i>	4,500	390	8.67%	nzsappers.org.nz	Defence Capability Plan outlined plans to expand the army to 6,000 personnel by 2035. (Est. of 3 Coys~130pax = 390)	NA
<i>Norway</i>	8,300	800	9.64%	MILENGCOE	3,900 regulars. Around one-third of troops are conscripts.	Engr Fce: 800

Evolving Challenges in Military Engineering

<i>Country</i>	<i>Land Component</i>	<i>Engr Forces</i>	<i>Percentage of Land Comp</i>	<i>Sources</i>	<i>Remarks</i>	<i>MILENG COE Data</i>
<i>Portugal</i>	13,350	1,040	7.79%	Military Balance (Exercito Portugal 2022)	Est. 8 Coys~130 pax = 1,040	NA
<i>Sweden</i>	6,850	910	13.28%	Military Balance (Försvarsmakten 2022)	Does NOT include HQ Coys or EOD & Search Coy which is now part of SWEDEC. Est. 7 Coys ~130 pax = 910	NA
<i>UK</i>	83,450	6,696	8.02%	Military Balance (Lancaster 2018) (UK MOD 2020)	Reserves: 3 x Engr Regt & 1 EOD Regt, 9 x STRE. 1 x Sqn with Joint Ger-UK Regt [Figures from 2018 figures plus 28 Regt – 6696]	Mil Force: 235,000; Engr Fce: 10,000 - 11.98%
Average Percentage of Engrs within Land Component:			11.22%			