Alang in Transition:

From Compliance to Capability

Strengthening the Human Foundations of Safe Ship Recycling

SSI
Sustainable
Shipping Initiative

Contents

Executive Summary

Ship recycling is undergoing significant change. In advanced ship recycling facilities, safety is no longer defined only by compliance with minimum standards and is increasingly shaped by how infrastructure investment, workforce knowledge, supervision systems and operational planning work together in practice. As global vessel retirements at the end of their economic lives increase over the coming decade, the challenge facing the industry is not only to continuously improve safety practices but to scale dismantling capacity while maintaining and strengthening safety capability.

This report examines one Hong Kong Convention (HKC) compliant ship recycling facility, Priya Blue, in Alang-Sosiya, Gujarat to understand how modern ship recycling safety operates on the ground and what this reveals about the industry's progress and future direction.

In Alang there is clear evidence of industry safety progress post HKC: formal occupational training and worker understanding of safety, certification for safe working conditions, and infrastructure upgrades have transformed many aspects of dismantling operations compared with earlier decades, demonstrating how safety improvement accelerates when worker wellbeing is a priority, and when regulation, investment and operational practice reinforce one another.

Safety capability depends on more than just infrastructure and procedures. Experienced supervisors, workforce continuity and operational knowledge play a critical role in translating formal systems into safe daily practice. At the Ship Recycling Facility studied, the Mukadam supervisory structure is a key example of how local knowledge and leadership support safe operations.

Safety risk evolves across dismantling stages. Primary cutting presents ignition and structural hazards; secondary cutting introduces coordination risks associated with cranes and suspended loads; and tertiary processing reduces structural hazards while increasing exposure to repetitive manual handling and ergonomic strain. Understanding this staged risk profile enables effective safety controls.

The challenge ahead is how the industry can scale dismantling capacity and safety capability across the Alang cluster evenly and safely, building human knowledge, operational systems and physical infrastructure that significantly higher dismantling volumes will require.

Many of the hazards encountered during dismantling originate from decisions made earlier in the vessel's (often 25 or 30 year) lifecycle. Structural complexity, incomplete hazardous material documentation and fragmented information across ownership changes can all increase risk exposure at the Ship Recycling Facility (here after called SRF).

Key insights from the case study:

- Significant progress has been made in HKC-certified facilities through infrastructure investment, mechanisation and structured safety management systems.
- Experienced supervision and workforce continuity are central to maintaining safe operations and transferring operational knowledge. This will be more relevant as the workforce is scaled-up in line with projected increase in demand.
- Safety risk evolves across dismantling stages, requiring different operational controls and supervision approaches.
- Local engineering adaptation has become an important safety asset where equipment designed specifically for ship recycling environments hardly yet exists.
- Decisions made earlier in the vessel lifecycle strongly influence the potential risks faced during dismantling.

These findings point to several opportunities for the wider industry to build on the progress already demonstrated by leading facilities:

- Documenting and disseminating operational knowledge from advanced facilities, including supervisory practices, staged risk management and locally developed engineering solutions, would accelerate industry-wide progress.
- There is an opportunity to support the development of equipment and tools designed specifically for ship recycling environments, drawing on the practical innovations already emerging within leading facilities.
- Digitising yard processes, from permit systems to safety management, and developing digital twin capabilities at the yard level would strengthen coordination, documentation and operational oversight.
- Embedding dismantling considerations into vessel design and documentation systems, including digital twin records that persist through a vessel's operational life, would reduce risk exposure and improve end-of-life safety outcomes.
- Developing an industry roadmap to 2050 would provide a structured framework for aligning investment, regulation and innovation across the ship recycling sector, setting clear milestones for safety performance, digitisation and the transition to more sustainable dismantling practices.

Together, these insights suggest that the next phase of improvement in ship recycling safety will depend on strengthening the connection between SRF level practice, industry collaboration and lifecycle accountability across the maritime system.

The Ship Recycling Industry in Transition

The global ship recycling industry is at a structural turning point. The entry into force of the HKC has created, for the first time, a binding international framework requiring recycling facilities in party states to meet defined standards of infrastructure, safety management and hazardous material handling. India, Bangladesh and Pakistan, which together account for 85% of the global tonnage of the global recycling tonnage, are all subject to this transition. This shift is further underscored by the European Union's Industrial Maritime Strategy, published on 5 March, which for the first time identifies India as a cooperation partner in maritime industrial transition.

Understanding where the industry currently stands requires acknowledging both the progress made and the unevenness of that progress. Over the past decade, a small number of leading facilities in India and, more recently, Bangladesh have made genuinely significant investments in infrastructure, mechanisation, training and management systems. These facilities consider compliance as the minimum baseline.

At the same time, compliance across the cluster is uneven. While the most advanced facilities operate at levels that go beyond the HKC baseline. There is unevenness in the levels across the cluster. This unevenness matters not only because workers at lower-performing facilities remain exposed to preventable risks, but because it shapes the broader trajectory of the industry.

When the same compliance designation can describe facilities operating at very different actual levels of safety performance, compliance rates alone cannot tell us how safe the industry is becoming.

This unevenness also has a geographic dimension worth noting. Bangladesh, Turkey and India represent three distinct contexts for safety capability development, shaped by different regulatory environments, industrial ecosystems and workforce conditions. Bangladesh's most advanced facilities have made rapid infrastructure investment in recent years. Turkey operates within European regulatory proximity and has developed a different model of formalised dismantling practice.

Alang's strength lies not in any single facility but in the depth of the industrial ecosystem surrounding it, the Mukadam knowledge base built over forty years, the secondary markets, and the recycling ecosystem of the cluster itself. Whether the Alang model is directly transferable to other contexts is an open question, and one the industry should examine carefully before assuming that certification alone can produce equivalent capability elsewhere.

Under the Recycling of Ships Act 2019, (recently amended in Jan 2026), India acceded to the Hong Kong Convention and designated the Directorate General of Shipping as the National Authority for Ship Recycling, with its office established in Gandhinagar to serve the Alang cluster directly. As the apex body, DG Shipping administers, supervises and monitors all ship recycling activity in India and represents India at the IMO. Of 128 operational plots, 115 are now HKC compliant, supported by cluster-wide infrastructure including a dedicated training institute, a Level 3 multi-speciality trauma hospital and a Treatment, Storage, and Disposal Facility (TSDF) regulated by the Gujarat Pollution Control Board (GPCB). These are not peripheral policy gestures; they reflect a government that has taken deliberate ownership of the industry's transition.

Looking ahead, the challenge is compounded by scale. The shipbuilding boom of the 2000s and early 2010s produced a large global fleet whose vessels are now approaching end of life in growing numbers. Annual recycling capacity will need to increase substantially over the next decade to absorb this volume. The Gujarat Maritime Board has completed a master plan committing 131,981 USD to expand capacity from 4.5 million to 9 million LDT by 2035. The question of safety capability is therefore not only about making current operations safer. It is about whether the industry can scale safely, building the human knowledge, operational systems and physical infrastructure that significantly higher dismantling volumes will require, without repeating the errors of earlier eras when expansion came at the expense of worker safety and environmental standards.

The composition and quantity of the future fleet arriving at the SRF will add a further layer of complexity to every part of the ecosystem, from the beach to the re-rolling mills. Large LNG carriers, very large container ships and vessels built with increasingly sophisticated structural systems carry challenging cutting geometries. The downstream steel network, calibrated over decades around the dimensions and grades of conventional vessel types and numbers, has not yet been tested. Whether that adaptation can happen safely, and at scale, is an open question.

The workforce question is equally unresolved. The Mukadam system, unique to Alang, works because knowledge accumulates and a worker moves from helper to cutter to supervisor over years. Absorbing the sensory and operational judgement that no training course can fully replace. More vessels require more of that knowledge, not less. But daily wage contracts, which govern most of the junior workforce at Alang, offer no structured pathway for that accumulation to happen with increasing seniority. A SRF that scales its throughput by hiring new workers on daily terms is not scaling its safety capability at the same rate. The gap between the two will widen precisely as the vessels arriving demand more from the people dismantling them.

Alang as an Integrated Industrial Ecosystem

Globally, most large ocean-going vessels are dismantled in South Asia, with India, Bangladesh and Pakistan currently accounting for 2/3 of the annual recycling tonnage. Among these locations, Alang in Gujarat has developed into one of the most significant ship recycling clusters in the world.

Since the 1980s, Alang has evolved into a specialised industrial ecosystem dedicated to the dismantling and material recovery of ocean-going vessels. Over time the region has developed supporting infrastructure, transport networks and downstream steel processing facilities that allow dismantled material to move efficiently into secondary manufacturing markets.

The coastline hosts numerous recycling plots where vessels are beached and dismantled. Once structural sections are removed from the vessel, they are transferred to secondary cutting areas where steel plates are reduced to sizes suitable for downstream processing. From there, material flows outward through a network of scrap traders, transport operators and steel processors. Nearby re-rolling mills in Bhavnagar and Sihor convert recovered steel plates into billets, reinforcement bars and structural sections used in the construction sector. Non-ferrous metals, machinery and reusable fittings move through refurbishment markets and secondary component traders.

The steel economy that Alang feeds is significant. India is now the world's second largest steel producer, and the ship recycling cluster is structurally integrated into that supply chain in a way that is rarely acknowledged in the international debate. Most of the steel recovered at Alang goes directly to the re-rolling mills of the Gujarat region — more than 80 mills operating in Sihor, converting ship plate into structural sections, beams and bars for use in construction.

The circular economy logic of ship recycling is therefore not abstract. It is embedded in the regional infrastructure of Gujarat through decades of co-evolution between the SRF and the mills that surround them.

At the time of this research, only a few SRFs were working at full operational capacity across Alang, it was described as a period of historically low activity reflecting the interplay of global freight rates and competitive pressure from neighbouring facilities. The SRF visited was among those working, and among those receiving more technically demanding vessels, a concentration that reflects its standing in the market.

Recovery rates at Alang approach 98% of vessel mass, making the cluster one of the most efficient material recovery systems in the global maritime industry. But that efficiency is inseparable from the operational intensity that produces it. Cutting operations and transport logistics must align with downstream processing capacity and market demand simultaneously. Safety management at the SRF therefore operates within a high-throughput industrial environment where sequencing, coordination and supervision are not optional, and where the pressures of the system are felt most directly by the people responsible for safe operations.

Part I

Inside the Ship Recycling Facility:

Safety Systems

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This section examines the internal operational systems that support safety capability within the Ship Recycling Facility.

1. Safety Baseline at the Ship Recycling Facility

Dismantling operations follow a staged reduction process in which an arriving vessel is progressively transformed into smaller steel sections and recyclable materials that move into downstream markets. As the physical scale of the material changes, the operational conditions under which workers interact with it also change. Each stage manages the existing hazards, but may then introduce new, different hazards, supervision requirements and operational controls. Understanding this staged material flow is therefore essential to understanding how safety is managed within the SRF.

Central to this is the Ship Recycling Facility Plan (SRFP), required under Regulation 19 of the Hong Kong Convention. The SRFP is a document that sets out the facility's organisational structure, safety management systems, hazardous material handling procedures and emergency response protocols. In practice, this translates into daily permit-to-work procedures, confined space entry protocols, hot work authorisations to name a few that guide safe and responsible operational activity.

1.1 Management Oversight and Supervisory Structure

Safety responsibilities are distributed across management including the HSE Manager, Safety Officers, technical personnel, and the supervisory staff ("Mukadam/s" in Hindi) who oversee compliance, training, hazardous material management and operational planning across the SRF.

HSE personnel oversee compliance, training and hazardous material management, while Mukadams, coordinate daily dismantling activities. Mukadams play a key central role in translating safety procedures into real-time supervision during cutting, lifting and material handling operations.

1.2. Highlighting The Mukadam and HSE managers system: Knowledge as safety infrastructure

Figure 1. HSE Manager seen giving instructions on the SRF. Photo: Author fieldwork, Alang (Feb 2026).

Alongside formal procedures, workforce organisation plays a critical role in translating safety requirements into practice. The Mukadam supervisory system is the most important safety asset in the SRF. It is a system of knowledge transfer built over generations of dismantling work, in which experienced supervisors who began as helpers have accumulated a form of operational understanding that is central to safe dismantling practices. The Mukadam workforce at Alang is almost entirely male, reflecting the broader gender composition of the dismantling workforce; this is not the result of formal policy or explicit corporate preference, but rather a continuation of historically male-dominated labour patterns in a heavy industrial sector, where progress toward gender balance has been gradual.

Each Mukadam oversees a small team of approx. 10 workers, and maintains direct oversight of cutting operations, worker positioning and crane movements across all operational stages. Acting as the link between management and frontline workers, they work with the HSE managers and are responsible for ensuring that operational instructions are followed, that hazards are pre-identified during cutting operations, and that the procedural framework of the SRFP is translated into real-time on the ground. They are an accumulated memory of how this work has changed, and the primary mechanism by which that knowledge is transmitted to the next generation of workers. One Mukadam, interviewed during fieldwork, described a career that began at the very bottom of the SRF hierarchy:

"I came to Alang twenty years ago as a helper. I was carrying things, moving things, helping the gas cutters. The Mukadam before me explained and taught everything to me. I learned by being near the people who knew. Now I am Mukadam, and it is my responsibility. I watch everything, every man, every cut. In those twenty years I have seen this place change completely. We did not have adequate safety equipment or procedures, I feel safer now than I did then. And the workers under me, they are safer too."

— Mukadam, twenty years at Alang

This account captures the lived continuity of a safety knowledge that has evolved through the people who inhabit it. The implication for safety capability growth is significant. Thus, workforce continuity is not a welfare consideration separate from operational safety. It is also a safety investment. Policies that support stable employment, clear career progression and long-term presence at a single facility are safety interventions in the most direct sense.

1.3 The Mukadam Language: A Locally Developed Communication System

One of the most distinctive and least documented features of the Mukadam system is the specialised vocabulary and set of physical communication that have developed organically across Alang over decades of dismantling work. The workforce at Alang is predominantly migrant, drawn from Gujarat, Rajasthan, Uttar Pradesh and other states, speaking a range of languages and dialects. Ship components carry technical designations that have no equivalent in the workers' spoken languages. The operational environment is loud, physically demanding and spatially complex. In this context, the development of a shared working vocabulary was a functional necessity.

Over time, Mukadams and their teams have developed local names for structural components that translate the geometry of the ship into terms that workers can understand and use. Terms such as "Nal", "Sulfi", "Pankha", "Dhamosa" describe sections of hull, structural frames, tank tops and accommodation blocks. The tacit knowledge developed over time regarding the weight and appearance of a section, its position relative to visible landmarks on the vessel, its behaviour when cut. These observations are not written down but exist entirely in use, passed from experienced workers to new arrivals through proximity and observation, in the same way the Mukadams themselves learned.

Alongside this vocabulary, a system of hand signals manage communication between Mukadams, crane operators and cutting teams across distances and in conditions where voice communication is unreliable.

This communication system is a safety asset of significant practical value. It is also largely undocumented. The documentation and formalisation of this system, done in a way that preserves its practical utility rather than abstracting it into procedure, represents one of the clearest and lowest-cost opportunities available to the cluster for preserving and transmitting operational safety knowledge. It also represents a potential contribution to global ship recycling practice: a working model of how operational language and signalling can be developed for the specific linguistic, acoustic and spatial conditions of this environment, rather than borrowed from industries where those conditions do not apply.

1.4 Worker Training and Competency

Worker competency is supported through a structured training system that combines mandatory external training with internal instruction at the facility. All personnel working in ship recycling facilities are required to complete the Gujarat Maritime Board (GMB) safety training programme, a twelve-day course that covers hazards in ship recycling, cutting operations, material handling, fire and explosion safety, emergency response and environmental awareness. Additional internal training is provided by the HSE team, including job-specific instruction for gas cutters, crane operators and hazardous material handlers. Workers also participate in periodic refresher sessions, safety campaigns and emergency response mock drills to maintain operational awareness and reinforce safe working practices.

1.5 Hazardous Material Management

Hazardous materials present within vessels are identified, marked and managed before structural dismantling begins. Materials such as asbestos, oils, residues, paints and other potentially hazardous substances are removed or isolated using dedicated procedures, as defined in the SRFP and SRP, and handled by trained personnel.

Designated containment areas and controlled storage systems are used to manage hazardous materials once removed from the vessel. These processes are supported by environmental monitoring systems, waste management protocols and coordination with authorised disposal facilities.

1.6 Infrastructure upgrades

Since the adoption of the HKC requirements by the SRF, in advance of its formal ratification, operates with demarcated work zones that separate primary cutting on the vessel from secondary plate reduction and tertiary sorting activities. Impermeable flooring has been introduced in key areas where secondary cutting and hazardous material handling take place, allowing better containment of runoff and reducing environmental exposure risks. Drainage channels direct potential contaminants toward controlled storage areas, while firefighting equipment and response systems are positioned at key cutting points.

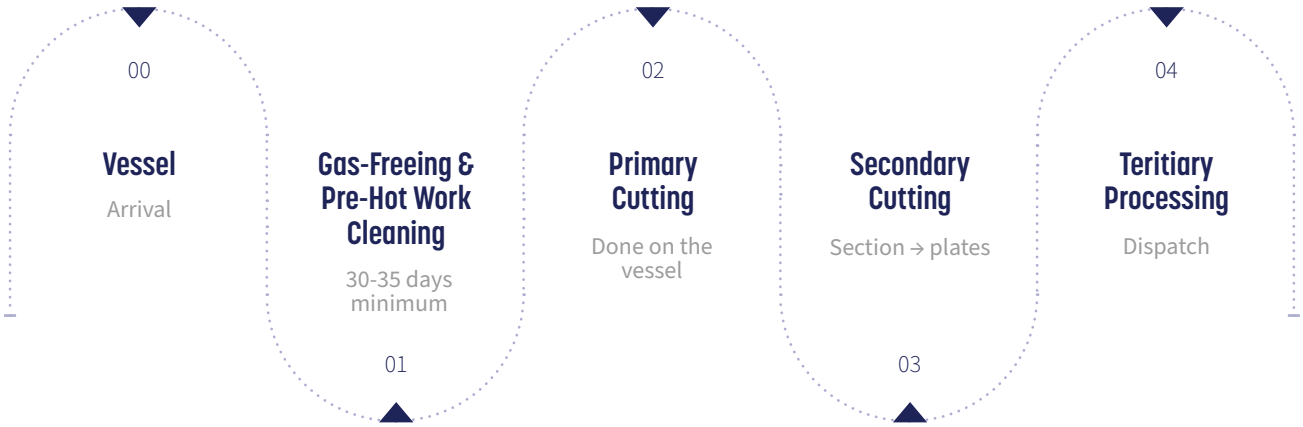
1.7 Emergency Preparedness and Response

Emergency preparedness forms an integral part of operational safety at the SRF. Dedicated response teams, firefighting equipment and evacuation procedures are established to respond to incidents such as fires, explosions or worker injury. Workers receive training in first aid, firefighting and emergency response procedures as part of their safety training programmes. Periodic mock drills are conducted to test response readiness and ensure that personnel are familiar with emergency protocols. The response to these drills is always recorded, and learning points are promulgated to the workers at the next opportunity to deliver continuous improvement.

2. Risk Across Dismantling Stages

Dismantling operations at the SRF follow a staged process through which a large ocean-going vessel is progressively reduced from an intact structure into smaller steel sections and recyclable materials that move into downstream industrial markets. As the physical scale of the material changes, so too do the operational conditions under which workers interact with it. Understanding how material moves through the dismantling process is therefore essential to understanding how safety processes operate within the facility. Each stage of reduction introduces a different set of hazards, supervision requirements and operational controls.

Safety risk changes in operating procedure and location across the four main operational phases, and at each phase a different set of controls, skills and forms of knowledge is required to manage it. While hazards become visible at the facility, many of the conditions shaping these risks originate earlier in the vessel lifecycle. Structural design choices, maintenance and repair and hazardous material documentation influence how vessels behave during dismantling and how risks emerge during dismantling operations. Within the facility itself, risk exposure varies across the three main dismantling stages: primary cutting, secondary cutting and tertiary processing.



Overview of Dismantling Stages

2.1. Pre-Hot Work Cleaning and Gas-Freeing:

Before any cutting can begin, the vessel must be prepared for hot work. This preparation phase focuses on removing residues and stabilising the internal atmosphere of the ship so that flame-based cutting operations can take place safely. A minimum of thirty to thirty-five days of preparation is now required before primary cutting commences, covering gas-freeing, hazardous material surveys and documented planning of the dismantling sequence.

Ships arrive at the SRF after operational lives of twenty to thirty years carrying the accumulated residues of that service. Fuel tanks, lubricating systems, bilge compartments and pipe networks often contain oils, sludge and chemical residues that have settled and thickened over years of operation. Cargo holds may retain traces of previously transported materials. These substances must be removed or neutralised before any heat source is introduced into the vessel.

Workers enter tanks and enclosed compartments to clean surfaces, remove residues and ventilate spaces. These activities take place within confined geometries where ventilation may be limited and where atmospheric conditions must be carefully monitored.

There are confined-space entry procedures and atmospheric testing required as per the SRFP before any workers enter enclosed spaces, and gas-free certification must be obtained before hot work is authorised. These tests to certify presence of a breathable atmosphere and absence of an explosive atmosphere are required to be repeated at least every shift, or more frequently if there has been a material change to the location. Rescue teams and standby personnel must remain in position during tank entry operations. Only once this preparation stage has been completed can the dismantling process move to structural cutting.

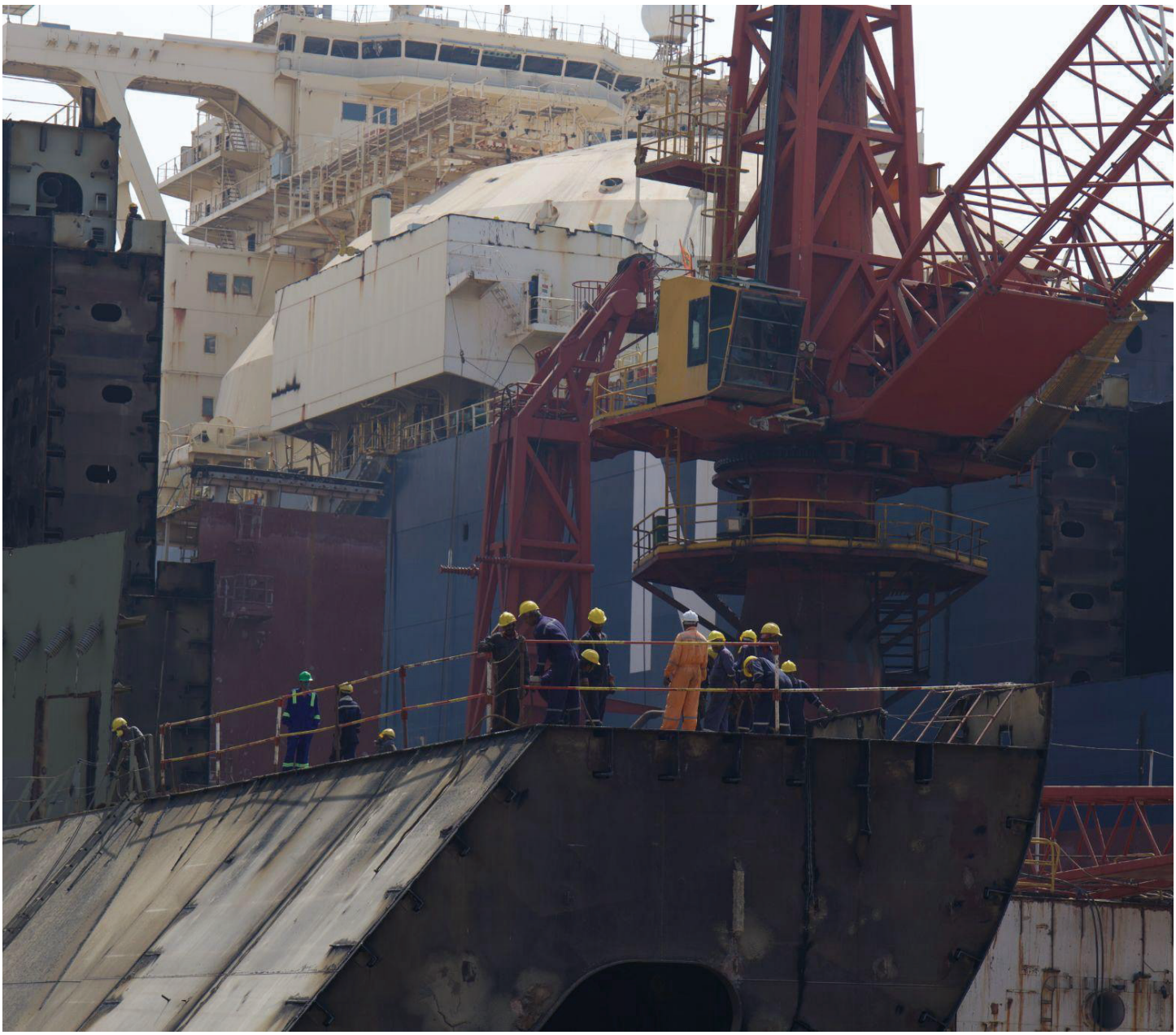


Figure 2. Primary cutting operation on the vessel. Mukadam is seen overseeing workers. Photo: Author fieldwork, Alang (Feb 2026).

2.2. Primary Cutting

Figure 3. Primary cutting operation on the vessel. Photo: Author fieldwork, Alang (Feb 20

Figure 4. Secondary cutting operation on the SRF.Photo: Author fieldwork, Alang (Feb 2026).

Figure 5. Two workers seen from inside a partially dismantled LNG carrier. Photo: Author fieldwork, Alang (Feb 2026).

Figure 6. Two workers seen inside a partially dismantled vessel. Photo: Author fieldwork, Alang (Feb 2026).

Figure 7. Worker on vessel during primary cutting Photo: Author fieldwork, Alang (Feb 2026).

Primary cutting marks the beginning of the vessel's physical transformation. Gas cutters work directly on the ship structure, progressively removing large sections of the hull and internal framing.

At this stage the ship remains an intact structure, and each cut alters how weight is distributed across the vessel. Structural sequencing therefore becomes central to the dismantling process. Naval architects provide structural calculations indicating which sections should be removed first and how large those sections can be relative to the crane capacity available in the SRF.

These estimates are typically set at approximately half of the crane's maximum lifting capacity. The supervisor then translates this structural plan into the day's operational sequence, coordinating cutting teams and crane operators so that sections can be safely removed and transferred to ground-level cutting areas.

Within this stage, certain parts of the vessel present more complex working conditions than others. The engine room is typically considered the most hazardous area during primary cutting because of its confined layout and dense concentration of machinery, piping and fuel systems. Work in these spaces requires careful ventilation and close supervision, as access routes are limited and visibility can be reduced.

In addition to spatial constraints, workers must also manage operational risks associated with flame cutting on painted steel surfaces. Before cutting begins, areas are often scraped to remove layers of paint that could ignite during hot work. As cutting progresses, any remaining paint can burn off and release smoke or sparks, requiring fire-watch personnel to remain present to monitor for ignition and respond quickly if fires occur. For this reason, hot work is closely supervised, with firefighting equipment positioned nearby and continuous oversight maintained during active cutting operations.

2.3. Secondary Cutting

Secondary cutting begins once large hull sections are transferred from the vessel onto prepared impermeable ground surfaces where they can be further reduced into manageable plates. At this stage, the nature of risk shifts away from structural instability toward coordination hazards between cutting operations and mechanised lifting systems.

Because heavy lifting and cutting work occur within the same operational environment, suspended loads, crane movements and cutting teams must operate in close proximity while maintaining safe spatial separation.

The SRF manages these interactions through a combination of sirens and physical demarcation, separating lifting corridors from cutting areas and, by design, excluding workers from active load zones Mukadams maintain close oversight to ensure that crane operators and cutting teams coordinate movements effectively.

As dismantling progresses and material throughput increases, the number of lift cycles rises, placing greater emphasis on sequencing, communication and operational discipline between teams.

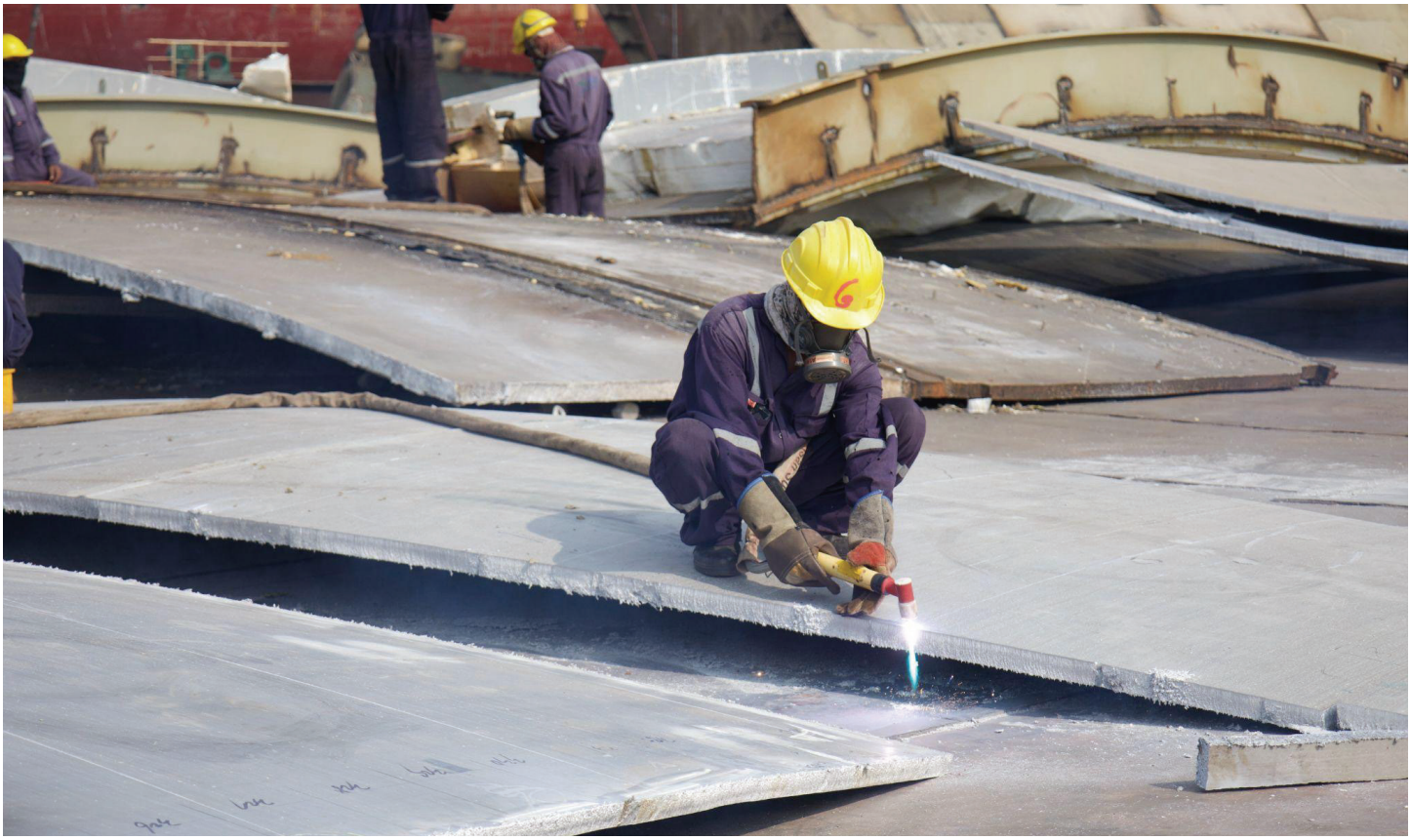


Figure 8. Gascutter cutting an aluminium panel during secondary cutting. Photo: Author fieldwork, Alang (Feb 2026).

Figure 9. Insulation material being lifted by barge crane after primary cutting. Photo: Author fieldwork, Alang (Feb 2026).

Figure 10. Secondary cutting operations on impermeable flooring. Photo: Author fieldwork, Alang (Feb 2026).

Figure 11. Secondary cutting operations on impermeable flooring by workers in blue and white. Photo: Author fieldwork, Alang (Feb 2026).

2.4. Tertiary Cutting:

Figure 12. Tertiary cutting operations in the backyard of the facility. Photo: Author fieldwork, Alang (Feb 2026).

The tertiary stage represents the final reduction and sorting phase of the dismantling process. Steel plates produced during secondary cutting are further reduced, sorted by grade and prepared for transport to downstream steel mills and scrap markets.

At this stage the scale of individual pieces of material has reduced significantly, but the volume of plates and scrap pieces being handled increases. Workers repeatedly reposition plates, conduct cutting operations and organise materials according to the requirements of downstream processors.

While the catastrophic hazards associated with structural instability or suspended loads decline during this stage, cumulative ergonomic risks become more prominent. Repetitive cutting motions, plate repositioning and manual handling tasks can expose workers to fatigue over long shifts.

The SRF addresses these risks through organised sorting areas and the use of magnetic cranes used to lift heavy steel material with significantly reduced human intervention to position the lifting gear, that reduces sustained lifting during repetitive tasks.

Figure 13. Tertiary segregation by worker in backyard of SRF. Photo: Author fieldwork, Alang (Feb 2026).

Figure 14. Steel bar after recycling. Photo: Author fieldwork, Alang (Feb 2026).

3. Filling the Equipment Gap: Locally Developed Solutions

The absence of equipment built specifically for ship recycling environments has produced a culture of locally engineered adaptation across Alang. Rather than relying solely on external machinery, ship recycling facilities have adapted existing equipment, built what does not yet exist and developed workshop capabilities that allow for repair components to be maintained and modified within the operational environment itself.

At the SRF observed, decommissioned offshore rigs equipped with crane systems, also known as barge cranes, have been positioned between vessels to support lifting operations during dismantling. These rigs were sourced with cranes already installed, repaired if required and certified in accordance with Indian law for operational use. Positioned alongside active vessels, they allow large hull sections to be lifted directly from primary cutting zones and placed onto impermeable ground surfaces in secondary cutting areas.

In parallel, the SRF as been developing a prototype winch system designed to support horizontal pulling operations during vessel beaching and block repositioning. Originally configured for vertical marine lifting, the adapted system aims to reduce manual rope handling and minimise physical strain during repositioning activities. The prototype remains under development and has not yet reached operational deployment. The development of this prototype illustrates the direction of travel within the SRF: locally engineered solutions emerging from the operational knowledge of people who understand both the equipment and the environment in which it must perform.

Figure 15. Original winch machine from a decommissioned ship undergoing modification. Photo: Author fieldwork, Alang (Feb 2026).

Figure 16. Designed modification to be retrofitted to the winch machine prior to re-testing and re-use. Photo: Author fieldwork, Alang (Feb 2026).

3.1 Infrastructure and Locally Engineered Developments

Progressive investment in SRF infrastructure has transformed the physical conditions under which dismantling occurs. Impermeable concrete surfaces in secondary cutting zones allow crawler cranes with electromagnets to move steel plates with significantly reduced manual labour intervention. Drainage and containment systems manage the environmental risk that previously went unaddressed. These changes improve both worker safety and operational efficiency simultaneously.

3.3 Locally Engineered Workshop Adaptations

SRF workshops maintain and modify a range of equipment to suit the specific conditions of dismantling operations. Tools that were originally designed for other marine or construction environments are adapted and independently certified for the heat, scale and operational rhythm of ship recycling work. This workshop capability is itself a safety asset: it reduces dependence on external supply chains for critical equipment maintenance and allows rapid response when tools fail during operations.

3.2 Fixed Tower Crane Installation and Lift Corridor Structuring

Fixed tower cranes are being built along a corridor between primary and secondary cutting zones. This allows large hull sections to be lifted directly from the vessel onto prepared ground.

Figure 17. The workshop engineer demonstrates why a standard manufactured component cannot be used as the dimensions do not match the machines requirements. A custom-fabricated part with unique measurements must be made specifically for this repair. Photo: Author fieldwork, Alang (Feb 2026).

Figure 18. A custom-fabricated part with unique measurements being made on a lathe machine Photo: Author fieldwork, Alang (Feb 2026).

3.4. Worker welfare and wellbeing

Most workers at Alang are migrant labourers from other Indian states. The labour contracts on daily wages, which matters for safety capability because the depth of induction, the quality of training and the continuity of workforce knowledge all depend partly on how the safety culture is passed on and communicated. Workers who move between facilities or return home seasonally carry knowledge with them when they leave. SRFs that invest in retaining workers, providing housing, training continuity and clear pathways for advancement, accumulate more of that knowledge over time and build the experienced Mukadam layer on which safety operations depend.

The human cost of this system deserves acknowledgment alongside its operational consequences. Workers who live far from home on short contracts, in accommodation that may be basic, without reliable access to clean potable water and food, adequate shelter from the weather, primary healthcare and with limited financial security, carry a burden that extends beyond the physical demands of the work itself. Mental and physical health, financial stress and social isolation are not conditions that safety procedures address, but they shape the capacity for sustained attention and safe decision-making that the work requires. SRF such as the one used for this case study, Priya Blue, that have invested in ILO-compliant dormitories, onsite medical facilities and worker social welfare programmes are not simply meeting a social responsibility benchmark. They are proactively managing a safety condition present in every operational shift.

Figure 19. Worker accommodation inside the SRF. Photo: Author fieldwork, Alang (Feb 2026).

Figure 20. For the migrant workers who choose to bring their families with them, the family accommodation with a playground for children and temple in the process of being built in the background. Photo: Author fieldwork, Alang (Feb 2026).

Part II

The System Around The Ship Recycling Facility

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This section examines external conditions that influence safety capability but remain largely outside the direct control of the SRF. The design of the vessels that arrive, the documentation that travels with them, the contract structures that govern the workforce, and the downstream systems that receive the materials the SRF produces all determine the environment within which dismantling occurs. This section examines those external conditions and what they mean for safety capability growth for a SRF.

4. Structural Design Complexity and Lifecycle Inheritance

One of the least visible but most significant factors shaping safety conditions at the facility is the structural complexity of the vessels being dismantled. Ships built in the 1990s and 2000s were designed for operational performance. Structural joints were welded for maximum strength under load. Hazardous materials were integrated for functional purposes: asbestos for insulation, lead-based paint for corrosion resistance, PCBs (in electric cable sheathing) for electrical stability. No part of the design process considered how these materials and structural configurations would be managed by workers cutting through them decades later.

In ship recycling, the consequences of design decisions made without dismantling in mind show up as inherited hazards in the facility. When a vessel arrives with incomplete hazardous material documentation, with structural configurations that make safe cutting access difficult, or with materials integrated into spaces that are hard to reach and poorly ventilated, the SRF absorbs the risk and cost of safely and responsibly managing their dismantling and removal. That cost is measured in preparation time, in the improvised responses required to manage unplanned hazards, and in potentially elevated risk exposure for the workers who carry out the work.

The Inventory of Hazardous Materials (IHM), required under the HKC and EU SRR, is the mechanism through which information about vessel hazards is passed from builders and owners to recyclers. Its completeness, accuracy and survival through multiple ownership transitions directly shapes the preparation burden and risk exposure of the SRF. Many vessels currently arrive at Alang with IHMs that are incomplete, out of date, or limited to materials surveyed at the point of initial certification. The practical consequence is that workers could encounter hazardous materials that were not anticipated in the Ship Recycling Plan, requiring prepared responses under operational conditions. Strengthening the IHM system is one of the highest-leverage interventions available to the recycling industry for improving safety conditions at the SRF level, and is found to be required by the SRF of ships that arrive.

5. High Material Recovery Rates and Throughput Intensity

The same ecosystem efficiency that makes Alang remarkable creates pressure on safety management. Recovery rates approaching ninety nine percent require continuous movement of material through the SRF alignment between cutting operations and downstream processing demand, and sustained high productivity from the workforce. When throughput pressure increases, the commercial temptation to compress preparation time, to consolidate crane movements or to accept higher operational density could become a pressure point. The density of simultaneous operations within the SRF peak throughput creates coordination challenges that safety procedures should be capable to address.

Managing this density safely requires not only procedures but real-time spatial awareness and communication systems that allow the management, Mukadam and supervisory layers to maintain an accurate picture of where every worker and every hazard is at any moment. As throughput grows, the demands on this coordination capacity grow with it.

6. Downstream management

The availability and quality of downstream waste management infrastructure shapes how hazardous materials are stored, transported and disposed of once removed from vessels. Roads, storage facilities and processing capacity for waste streams including asbestos, PCBs, oils and sludges all affect how safely the end-to-end recycling process operates. Underfunding of this infrastructure across the South Asian recycling cluster is a structural constraint on safety capability growth across the region, and one that requires government and industry investment beyond what individual SRF an provide.

Part III

Opportunities For Capability Development

Part III:

Opportunities For
Capability Development

The observations from this case study also point toward several areas where the industry could strengthen safety capability further.

7. From tacit knowledge to documented knowledge

The industries that have managed complex high-hazard environments longest, e.g nuclear, offshore oil and gas, aviation etc., share a consistent finding: the knowledge that keeps people safe is not only dependent on the manual. It lives in the people who have done the work, and it survives only when there are deliberate systems for capturing and transmitting it. The Mukadam system at Alang has developed precisely this kind of knowledge over four decades. Investing in its documentation and transmission would strengthen safety capability across the entire cluster, not only at the SRF where the knowledge currently resides.

8. Emerging Automation in Ship Recycling

There are emerging proposals to replace manual cutting processes with fully mechanised systems, including robotic high-pressure water cutting. While these technologies show clear potential to reduce direct exposure to hazardous tasks and are being actively explored through pilot projects and research initiatives, they remain at an early stage of industrial adoption. Given the variability and complexity of vessels arriving for dismantling, rather than replacing labour, the more realistic trajectory is toward hybrid human–machine systems, where automation supports specific high-risk or precision tasks. In this context, the role of the workforce becomes more, not less, critical. Effective integration of such technologies will depend on strengthening worker training, ensuring that operators can interpret, manage and intervene in increasingly instrumented and partially automated environments.

9. Digital Twin and Data-Driven Ship Recycling Facility Operations

Ship recycling facilities operate within highly dynamic environments where, despite the workflow design intents, cutting teams, crane operations and vehicle movements may often occur simultaneously within limited space. As dismantling progresses, these activities intensify, increasing the potential for operational congestion and coordination challenges. Frequent re-mapping the spatial and temporal patterns of facility activity would help identify where and when such congestion is most likely to occur. Developing a clearer understanding of these patterns would support more deliberate spatial planning, improved sequencing of lifting and cutting operations, and the design of safer operational corridors within the facility.

Facility operations at Alang currently rely on manual coordination systems for crane scheduling, personnel tracking and material flow. Digital twin modelling of SRF operations, in which a virtual representation of the SRF s maintained in real time and used to identify congestion, predict lift conflicts or optimise work sequencing, locate dismantled materials across the SRF, represents an opportunity to extend the coordination capacity of the supervisory system significantly.

RFID worker location tracking, already in use at some leading facilities, provides the data infrastructure from which such systems could be built. AI-assisted gas detection systems that integrate sensor data from multiple monitoring points across the vessel could extend the pre-cleaning monitoring capability, providing the Mukadam with an instrumented layer of awareness to complement his observational one.

10. Design for Dismantling and Design for Safety

The most significant long-term opportunity for safety capability growth in ship recycling is the integration of dismantling considerations into vessel design. Ships built today will arrive at SRF in the 2040s and 2050s. The workers who will dismantle them will inherit the decisions made now about structural configuration, material selection and hazardous material documentation. If those decisions are made without any thought for the end of life, those workers will face the same inherited hazards that SRFs and their workers in Alang manage today from vessels designed in the 1990s.

A 2021 cross-industry workshop convened by the UK Nuclear Decommissioning Authority, bringing together the nuclear, oil and gas, offshore renewables and defence sectors found the same pattern repeated across all of them: from Sellafield in the 1940s to the North Sea oil platforms of the 1970s and 80s, effort and investment was focused on getting the job done, with little or no thought given to end-of-life.

When decommissioning eventually became a regulatory requirement, industries discovered that structures designed without removability in mind imposed significant additional costs and hazards with one documented case requiring eleven years of preparation for a decommissioning operation that took three weeks to complete. The oil and gas sector has since developed economic models demonstrating that a 35% reduction in decommissioning costs also produces an 8% increase in a project's net present value, establishing a financial case, not only a safety one, for integrating end-of-life thinking at the design stage.

A comparable shift can be observed in the automotive sector under the End-of-Life Vehicles Directive, which requires vehicles to be designed for dismantling, reuse and recovery, embedding end-of-life considerations directly into product design and manufacturing systems. The workshop's central conclusion was unambiguous: it is essential not to repeat the issues we are dealing with now. Ship recycling is at an earlier but recognisably parallel point in that same transition.

Ship recycling does not yet have an equivalent discipline or community of practice within naval architecture that asks how structural joints will be managed by a gas cutter, how insulation materials will be removed safely from confined spaces, or how the hazardous material inventory of a vessel will survive multiple ownership changes over thirty years. The IHM is a step in this direction. The industry needs the development of design for dismantling as a formal consideration within naval architecture, supported by cross-industry learning from sectors that have already made this transition, and incentivised through regulatory and commercial mechanisms.

In 2018, Lloyd's Register Foundation commissioned a Foresight Review on Design for Safety from the Royal College of Art's School of Design, bringing together an international panel of experts from industry, government, academia and regulatory bodies to ask how design could be used as a strategic tool to reduce safety risk across complex systems. It positions safety not as a property of individual components or compliance documents, but as a quality of the whole system. The review calls explicitly for designing with rather than designing for, a collaborative, human-centred approach in which the people who do the work are recognised as essential contributors to safe outcomes, not merely recipients of procedures handed down to them. An additional layer is where the tools and equipment are developed for the specific conditions in which they will be used.

11. Toward a Vessel End-of-Life Passport

One potential mechanism for improving lifecycle transparency is the development of a vessel end-of-life passport that extends the current Inventory of Hazardous Materials into a continuously updated digital record across the vessel's operational life. Such a system could integrate material data, maintenance history and structural modifications into a single documentation framework that remains attached to the vessel across ownership transfers. For facilties, access to reliable lifecycle documentation would significantly reduce preparation uncertainty and allow dismantling plans to be developed with greater accuracy, directly leading to higher levels of worker safety and environmental responsibility in the dismantling operational process itself.

Aviation offers a directly relevant model. The aircraft dismantling sector achieves material recovery rates comparable to Alang but does so with a documentation infrastructure that makes the process substantially more predictable. Every aircraft arrives at its dismantling facility with a complete maintenance history, a verified component record and a known hazardous material inventory, the documentation created for operational safety reasons that produces end-of-life benefits as a byproduct. Dismantlers spend less time on preparation, face fewer unplanned hazards during cutting, and can plan operations with a degree of certainty that ship recyclers currently cannot. The difference is not technical capability. It is the presence or absence of a record that travels with the asset through its entire life.

12. Building a safety culture where Near Miss reporting is supported

A strong near-miss reporting system helps build a proactive safety culture when workers are involved not only in identifying events but also in analysing them. When workers can see what was learned and what changed as a result, reporting becomes a shared learning process that builds engagement, ownership and collective awareness of risk.

An increase in near-miss reporting should therefore be understood as a sign of a more transparent and responsive safety environment rather than a more dangerous one. Safety cultures strengthen when workers feel able to raise observations, participate in reviewing incidents and contribute to improvements in procedures, tools and operational planning. When reporting leads to visible changes, it reinforces trust in the system and encourages continuous attention to risk across the workforce.

Part IV

Key Insights

Part IV:

Key Insights

The following insights summarise the key findings of the report and identify factors that influence long-term safety capability development.

1. Safety capability develops through systems, not single interventions

Safety performance is not achieved through individual compliance measures alone. It emerges from the interaction of multiple elements including workforce training, supervision structures, infrastructure investment, operational sequencing, communication practices and equipment reliability.

Strengthening safety therefore requires attention to the overall operational system, rather than isolated improvements.

2. Local engineering innovation is an important safety asset

Several safety improvements observed at the SRF were developed through local engineering adaptation, including modifications to winch systems, crane placement strategies and workshop-based tool repair.
Supporting local technical capability allows SRFs to adapt equipment and processes to the specific conditions of ship dismantling.

3. Supervision structures and communication systems are critical

Safety procedures are translated into daily practice through supervision and communication. The Mukadam supervisory system, combined with multilingual communication practices, plays an important role in coordinating cutting operations, crane movements and worker positioning.

Strong communication systems help ensure that safety procedures remain active during complex operations.

4. Operational density introduces new coordination risks

As facilities increase mechanisation and material recovery efficiency, the nature of risk changes. Higher throughput and increased crane usage improve productivity but also introduce new coordination challenges, particularly around:

- Suspended load exposure, and worker exposure during un/rigging and un/slinging of loads using legacy/non-magnetic cranes
- Spatial congestion
- Simultaneous operations in shared work zones

5. Opportunities for future development

Looking ahead, several emerging tools and approaches from other high-risk industries may offer useful opportunities for ship recycling, including:

- Digital twin modelling for SRF operations
- Enhanced lifecycle documentation systems
- Utilizing RFID systems to locate the material from the ship and document its movement across the SRF for developing accurate grading of steel recovered from the vessel.

6. Risk redistribution across the vessel lifecycle

Many of the hazards encountered during dismantling originate from earlier decisions made during ship design, construction and operation.

Limited documentation of hazardous materials, complex structural configurations and the absence of design-for-disassembly considerations increase the risks faced by recycling workers. Strengthening lifecycle accountability across shipowners, designers and regulators could reduce these inherited risks and support safer end-of-life vessel management.

7. Workforce Continuity and Knowledge Retention

The accumulated operational knowledge of experienced supervisors and workers is the primary safety infrastructure of any high-performing facility. Contract structures, housing conditions, career pathways and worker welfare all affect whether that knowledge stays in the system or leaves with the people who carry it. Safety capability grows when the facility retains the people who know the work. The Mukadam system is the clearest expression of this principle, and its continuity, including the succession of experienced supervisors and the preservation of the communication systems they have developed, must be treated as a safety investment.

Conclusion

Ship recycling is entering a period of transition. The entry into force of the Hong Kong International Convention has established, for the first time, a global baseline for infrastructure, safety management and hazardous material control in recycling facilities. For many facilities, this marks a shift from more informal dismantling practices toward increasingly structured industrial systems.

This case study shows that meaningful progress is possible within that framework. Infrastructure investment, mechanisation, permit systems and structured training have already begun to reshape how dismantling operations are organised. At the same time, the study highlights that safety capability does not emerge from compliance alone. It develops through the interaction of infrastructure, operational procedures, supervision structures and workforce knowledge.

The findings also illustrate how many of the risks encountered during dismantling originate earlier in the vessel lifecycle. Structural complexity, hazardous material documentation and design decisions made decades earlier all shape the environment in which recycling workers operate. Improving safety outcomes therefore requires stronger lifecycle accountability across ship design, ownership and regulatory systems.

As increasing numbers of vessels approach retirement over the next decade, recycling capacity will need to expand. Ensuring that this growth occurs safely will depend on continued investment in infrastructure across the Alang cluster, workforce capability and operational knowledge. Strengthening safety capability across the ship recycling industry will remain an important part of the maritime sector's broader transition toward more sustainable practices.

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