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SHIPBREAKING IN BANGLADESH: PERSPECTIVES FROM INDUSTRIAL ECOLOGY, POLITICAL ECOLOGY AND ENVIRONMENTAL POLICY

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SHIPBREAKING IN BANGLADESH: PERSPECTIVES FROM INDUSTRIAL ECOLOGY, POLITICAL ECOLOGY AND ENVIRONMENTAL POLICY

By

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To the remembrance of almighty *Allah,*

and

To my mother

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Preface:

Chapter 1: SMMR and ALM designed research, SMMR performed research; SMMR analyzed data; SMMR and ALM wrote the paper.

Chapter 2: SMMR designed research with input from RH; SMMR performed research, SMMR and RH analyzed data, SMMR and ALM wrote the paper.

Chapter 3: SMMR and ALM designed research, SMMR performed research; SMMR analyzed data; SMMR, CS, ESN and ALM wrote the paper.

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List of abbreviations:

ACM: Asbestos-containing Materials

BC: Basel Convention

BECA: Bangladesh Environment Conservation Act

BELA: Bangladesh Environmental Lawyers Association

BLA: Bangladesh Labor Act

DALY: Disability Adjusted Life Years

ETP: Effluent Treatment Plant

EQ: Ecosystem Quality

FIDH: International Federation for Human Rights

GHG: Greenhouse Gas

GWP: Global Warming Potentials

HKC: Hong Kong Convention

ILO: International Labor Organization

IMO: International Maritime Organization

IPCC: Intergovernmental Panel on Climate Change

JICA: Japan International Cooperation Agency

LCA: Life Cycle Assessment

LCI: Life Cycle Inventory

LCIA: Life Cycle Impact Assessment

LDT: Light Displacement Tonnage

LPG: Liquid Petroleum Gas

NGO: Non-governmental Organization

NOC: No Objection Certificate

OECD: Organization for Economic Co-operation and Development

PAF: Potentially Affected Fractions

PDF: Potentially Disappeared Fractions

POO: Probability Of Occurrence

POP: Persistent Organic Pollutant

SBSRB: Ship Building and Ship Recycling Board

SBSRR: Ship Breaking and Ship Recycling Rule

SRF: Ship Recycling Facility

SRP: Ship Recycling Plan

YPSA: Youth Power in Social Action

Abstract:

The international shipbreaking industry connects developed and developing countries through the spatial and temporal flow of resources, both transported by the ships and by the recycling of the ships themselves. Many products for the public (such as documentaries and magazine articles) focus on the workers who dismantle these ships, often with minimal protection; the appalling images of shipbreaking yard workers and their polluted surrounds have garnered immense global attention and calls for better regulations.

In this dissertation, I examine how these environmental and worker rights issues can be understood through multiple disciplinary perspectives – industrial ecology (and one of its commonly used tools, Life Cycle Assessment), political ecology and environmental policy. Through an industrial ecology perspective, I examine how the social embeddedness in Bangladesh influences the flow of recycled scrap metal thorough the country. My study suggests that reciprocal and trust-based business connections provide the necessary leverage to maintain the flow of scrap resources from the Chittagong ship breaking yards on the coast to the metalsmith community in Old Dhaka.

In chapter two, I use Life Cycle Analysis (LCA) to assess the impacts of the shipbreaking industry on local environmental conditions and worker health. The results of the LCA pose a considerable challenge to the dominant narrative of the industry as wholly negative and unredeemable. My study suggests that shipbreaking

produces much less pollution and risks to human health than a similar process using virgin ore would. My results also suggest that the rerolling operations (to produce rebar) – rather than the beached ship cutting and in-yard processing – are more environmentally damaging. Among localized concerns, gas torching poses considerable health challenges to the cuttermen in the yard.

In chapter three, I investigate the drivers behind the persistent negative images of shipbreaking. This dominant narrative is maintained by Non-Governmental Organizations (NGOs) and their selective focus on pollution and accidents while ignoring improvements in the industry (e.g., introducing new technologies for managing the resources). My interviews with local stakeholders suggest that there are considerable image politics among the local NGOs that divert attention away from the global drivers of these impacts. Using political ecology to frame the scalar politics involved, I found that shipbreaking constitutes a simultaneous interplay of multiple scales, and that the NGOs' insistence on a local scale solution detracts from the sorely needed policy reforms at national and global scales.

The last empirical chapter identifies regulatory gaps in the international treaties and domestic regulatory regimes. In particular, a significant gap exists in international treaties regarding the provision of a funding mechanism to assist developing countries such as Bangladesh. I recommend that adopting a viable financial mechanism – deposit-refund systems – and forming a recycling states alliance would greatly improve shipbreaking conditions globally.

Chapter 1: How social ties influence metal resource flows in the Bangladesh ship recycling industry[1]

S.M. Mizanur Rahman and Audrey L. Mayer

Highlights

- Ship recycling provides local and global services for metal resource recycling
- Metal resource flows in Bangladesh are driven by social networks
- Successful industrial recycling clusters use social embeddedness to maintain resource flows

Abstract

The ship recycling industry in Bangladesh provides critical metal resources for construction and consumer products in the country, which has no native metal sources. This industry illustrates how industrial recycling can arise in a self-organized manner

[1] An earlier version of this work has been accepted for publication in the journal *Resources, Conservation and Recycling,* published by Elsevier. I thank Elsevier for granting permission documented in a supplementary file.

and be maintained through social embeddedness. Information provided through interviews with shipyard owners, traders, and blacksmiths illustrate the importance of historical, cognitive, structural, and cultural embeddedness to maintaining the flow of metals from the ships beached in the coastal city of Chittagong to the capitol city of Dhaka, more than 300 km away. The industry began through small scale metal scavenging; the early scavengers developed the major metal trading businesses operating today, maintained by family relationships. The metalworking community maintains a balance between the strong family ties and weak social ties, ensuring an optimum flow of information among the businessmen in the community. The engagement with scrap handling produces a sense of pride and a pleasure of innovation that binds this community with waste recycling. Thus, the embeddedness of this community through self-recruitment and trade information via social ties directs the resource flows in the community.

Keywords: Bangladesh; metal; ship recycling; social embeddedness

1.1 Introduction

The field of industrial ecology tends to focus on technical factors driving the flow of materials through industrial systems. However, social factors (such as how community influences these flows) can be equally critical to improving the sustainability of industrial systems (Ehrenfeld and Gertler 1997, Cohen-Rosenthal 2000, Gibbs 2003, Hoffman 2003, Boons and Janssen 2004, Asim et al. 2012, Boons and Spekkink 2012, Umair et al. 2015). While economic factors such as minimized transaction costs, sales of by-products, and reduced waste removal costs can motivate firm owners to participate in a clustering of industries, Ehrenfeld et al. (1997) argued that other factors such as risk of discontinuity, cost of standby supplies, insufficient information flows, distrust and opportunistic behavior may overwhelm the benefits and obstruct cluster participation. Therefore, the subtle interaction of financial gain and a sense of community is critical for building and maintaining industrial clusters, where business competitiveness is partially mitigated by cooperation and collaboration (Ehrenfeld and Gertler 1997, Nadvi 1999a&b, Cohen-Rosenthal 2000). This social component is developed over time, preconditioned by broad social arrangements that require maintenance to support the formative process of industrial clusters (Gibbs 2003, Ashton 2008, Howard-Grenville and Paquin 2008, Paquin and Howard-Grenville 2009).

In an industrial surgical cluster in Pakistan, Nadvi (1999b) showed that social networks moderated the level of competition among firms. Superficially, firm owners who exchanged materials appeared to adhere to a competitive mentality, illustrated by a statement from a businessman that ‘business is business, family is family’ (Nadvi 1999b). However, a tradition of mutualistic information flow regarding market demand and supply of raw materials provided benefits of ‘joint action’ and reduced the risk of loss. Likewise, the industrial cluster in Kalundborg, Denmark continues to demonstrate the importance of a social network through a club that encourages familiarity among managers, facilitating business interactions (Boons and Janssen 2004). Conversely, a top-down approach to building industrial networks by clustering firms has not proved effective. Chertow and Ashton (2009) found that in Puerto Rico, arranging firms to be spatially adjacent was not sufficient for cluster formation, as proximity did not intensify the firm level communication necessary to facilitate forward and backward linkages of by-products and wastes (Chertow and Ashton 2009). The critical element of social ties (facilitating communication) in industrial clusters in Pakistan and Denmark was missing in Puerto Rico, demonstrating the need for a 'thick web' of social connections among firm managers.

A growing number of studies consider how resource flows are influenced by social components (Nadvi 1999b, Boons and Jansen 2004, Domenech and Davies 2009, Asim et al. 2012, Boons and Spekkink 2012, Chertow and Ashton 2012). For example, Domenech and Davies (2009) applied social network analysis to evaluate the social aspects of two renowned case studies, Kalundborg (Denmark) and the National Industrial Symbiosis Programme (NISP) (UK). Here, we add to this growing collection of case studies focused on the embedded social relationships, which influence the flow of recycled metal in the ship recycling industry in Bangladesh.

Social embeddedness refers to a social context where individuals abide by certain rules developed over time through long-term reciprocity and exchanges (Uzzi

1997, Boons and Howard-Grenville 2009). This context provides three main benefits. First, social connections produce good will, confidence, reciprocity and trust through long-term interdependence. Second, connectedness minimizes destructive opportunism through a fear of seclusion from the community. Finally, connectedness encourages the transfer of knowledge and skills to the next generation (Nadvi 1999b). Game theory, prisoner's dilemma, and social choice theory all suggest that increased dialogue among actors may lead to socially optimum decision making and enhanced pressure to participate in activities that serve only collective interests (Alexander and Skyrms 1999, Desrochers 2001, Boons and Janssen 2004). The management of common pool resources is one example where people exemplify a cooperative mentality that maximizes resource productivity at the group level (Ostrom et al. 1999).

The influence of social embeddedness on industrial activity is likely to vary across firms and depend upon existing network layers (Hewes and Lyons 2008, Chertow and Ashton 2009). The extent to which these networks influence decision making processes in the community matters. Chertow and Ashton (2009) considered five aspects of embeddedness related to cluster formation: each individual's understanding level among others in the community as described by Ehrenfeld et al. (1997) as 'short mental distance' (the cognitive element; see also Jacobsen and Anderberg 2003); social norms and values regarding cooperation (the cultural element); the frequency of interpersonal transactions (the structural element); the process of power center formation (the political element); and proximity of the firms in the cluster and historical identity of the community (the spatial and temporal elements).

Here we focus on resource flows and social connections simultaneously in the Bangladesh ship recycling industry. The international ship recycling industry, while praised for its contribution to closing the loop in metals resources, demands a closer inspection in how the metal scrap is managed by local actors (Lyons et al. 2009, Sarraf 2010). Industrial ecology can improve local environmental conditions, but only if social networks and impacts are taken into account (Asim et al. 2012, Umair et al. 2015). We explore why resources from ship breaking yards in Chittagong are transferred to Old Dhaka, around three hundred kilometers away. Thousands of small and medium firms have developed in Old Dhaka to process scrap metal, and the area is now famous for highly specialized knowledge and skill, along with unique social and cultural attributes. Community is defined by the groups of people engaged in metal businesses. In our study, we have an Old Dhaka Community that represents Postogola and Dholaikhal metal workers, and a Bhatiary community in Chittagong. We hypothesize that it is the close social network (based on cultural identity) among businesses and other forms of social embeddedness that maintain the powerful draw of metal scrap resources towards Dhaka. We expect that both the network and the available resources work together to maintain the self-organized, diverse, and productive recycling cluster that transforms the scrap into products in high demand.

1.2 Study Sites

The ship breaking and recycling industry in Bangladesh decomposes end-of-life ships into steel and other engineered products for domestic consumers, recycling every part of the hull and machinery (Sarraf 2010). The activity started in Chittagong when a ship was stranded on the beach after a cyclone in the 1960's. Stuck in the sand, the aged ship was economically infeasible to recover and remained there for years before it was scavenged by locals. During the independence war in 1971, a few stranded ships were also scavenged by locals. An organized ship recycling industry finally started in the 1980's (FIDH 2002). By 2008, the majority of the 704 commercial ships scrapped world-wide were scrapped in Bangladesh and India. In 2009, out of 1014 ships, about 200 (21%) were dismantled in Chittagong (Demaria 2010, Sarraf 2010, Gregson et al. 2012). As of 2010, there were about 119 active ship breaking yards in Chittagong, an upward trend after 2008 when only 57 yards were operational due to a temporary ban on this activity by the Bangladesh Supreme Court in response to a writ petition against increasing fire explosions in the yards (Gregson et al. 2012). The ship breaking yards in Chittagong stretch about 20 kilometers along the coast, primarily in the Sitakunda Thana region (Gregson et al. 2012; Figure 1.1). There are over 60 ship recycling yards in this region, and the size of each yard is about 200-300 m^2. Hundreds of small trading shops filled with secondary products from the yards line the roads in Sitakunda; these shops vary in size from 30 to 50 square meters.

Each shop sells specific products bought from the yards. This is the first stage of sorting of the reclaimed materials after they are stripped from the ships.

Re-rollable ferrous scrap and iron plates account for 30-35 percent of total weight and 25 percent of the materials' value after breaking (Table 1.1). Reusable metal sheets of high quality represent about 40 percent of total weight and market value. Other scrap categories are less valuable but have a greater social impact on the small and medium enterprises, particularly in the Old Dhaka industries (Gregson et al. 2010).

Table 1.1: Percentage by weights and value of type of scraps recovered from an average ship (Upadhyay 2002)

Type of resources	Weights in percentage	Value in percentage
Re-rollable ferrous scrap	30-35	25
Reusable metal sheets	40	40
Re- conditioned machinery	10-15	25
Re-melting scrap	3	2
Cable, , stainless steel, Cu, brass	1	7
Furnace oil and oils, paints	2	0.50
Wooden and furniture	2	0.50
Burning, cutting losses and wastes	5-10	0

The industry (in Bangladesh and elsewhere) is often criticized for its environmental contamination and insufficient worker safety measures (Chapter 3; Hossain et al. 2008, Demaria 2010, Siddiquee et al. 2012, Abdullah et al. 2013). Shipyards are established through mangrove deforestation, and tests of coastal waters around shipyards have found elevated levels of oil, heavy metals, PCBs, asbestos, and other toxic pollutants. Particularly in the past, workers were exposed to a variety of immediate threats, from toxic air inside the ships to injuries from falling debris, as well as chronic effects from exposure to toxins and asbestos. However, the shipbreaking industry provides benefits to Old Dhaka and Bhatiary communities and the country through jobs and metal resources. International treaties, such as the 2009 Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships (Chang et al. 2010), aim to allow the shipbreaking industry to continue in countries such as Bangladesh with improved environmental and worker protections.

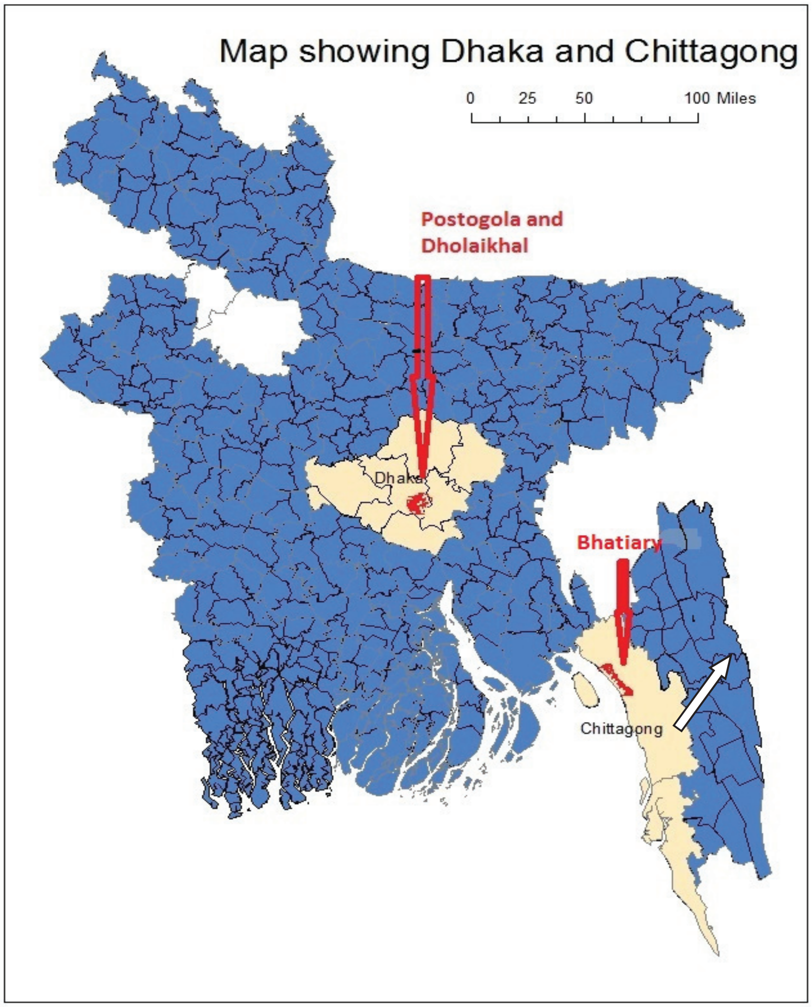


Figure 1.1: Study sites: Postogola and Dholaikhal neighborhoods are in Dhaka and Bhatiary agglomeration is in Chittagong

1.3 Methods

To understand the relationship between social embeddedness and resource flows, we used a questionnaire with a mixture of closed- and open-ended questions, verbally delivered to several representative groups: businessmen in the metal working industry (shop owners, metal traders/middle men, shipbreaking yard supervisors); workers and day laborers; and local people. Local people were those who live in the locality but were not involved in this business and worked in other professions such as teachers, boatmen and students. We focused our questionnaires on three neighborhoods: Postogola and Dholaikhal (in Dhaka), and Bhatiary (in Chittagong). The Postogola neighborhood is about 5 km^2 and is situated on the bank of Burigonga River, which surrounds the capital city Dhaka, Bangladesh (Figure 1.1); hundreds of enterprises conduct their business there. Business owners are residents of this region and are noted for their own cultural differences with respect to rest of Dhaka. The Dholaikhal neighborhood is about four to five kilometers from Postogola, and roughly the same size. Historically, this part of Dhaka has always been a business center dominated by traditional industries, such as metal recycling. The specific accent of Bengali language, low education rate, special food items, and marriage ceremonies distinguish the inhabitants of Old Dhaka from those cultures in "new" Dhaka. While the Old Dhaka people maintain their linguistic accent and marriage ceremonies as traditions, they do not seem to pursue them in order to maintain the difference. However, they pride themselves for their attachment to these traditional rituals and professions. For example, one respondent said that "this way of talking in Bangla is original. They [people in new Dhaka] speak in a new style, which is not ours. We speak what we got." Their cultural changes mainly revolve around changes in their professional involvement as their day-to-day information is sourced through their professional networks (Jahan et al. 2011). Businessmen in Bhatiary (in the Sitakunda yards) were also interviewed. Bhatiary scrap shops are scattered on either side of the Dhaka-Chittagong Highway, only two kilometers away from the yards.

The full questionnaire usually consumed 40-50 minutes and covered five topics: Family ties, social interaction pattern, intergenerational skill, material or resource sharing, and business or economic benefits. We also gathered information about their education level, number of children attending school, and number of siblings/relatives involved in the metal recycling businessmen. To gain the trust of the interviewees and ensure an open dialogue, conversations started informally and were not recorded. The interview was conducted in Bangla and translated to English. The full questionnaire was used until a saturation point of information was reached; this occurred at about 15 respondents in the ship recycling yards, and 20 respondents in Postogola. After this saturation point, we shifted to a shorter survey with fewer questions in order to get more baseline information with an expanded number of people (Table 1.2). In total, we interviewed 83 people.

Table 1.2: Distribution of interviewees across regions and employment

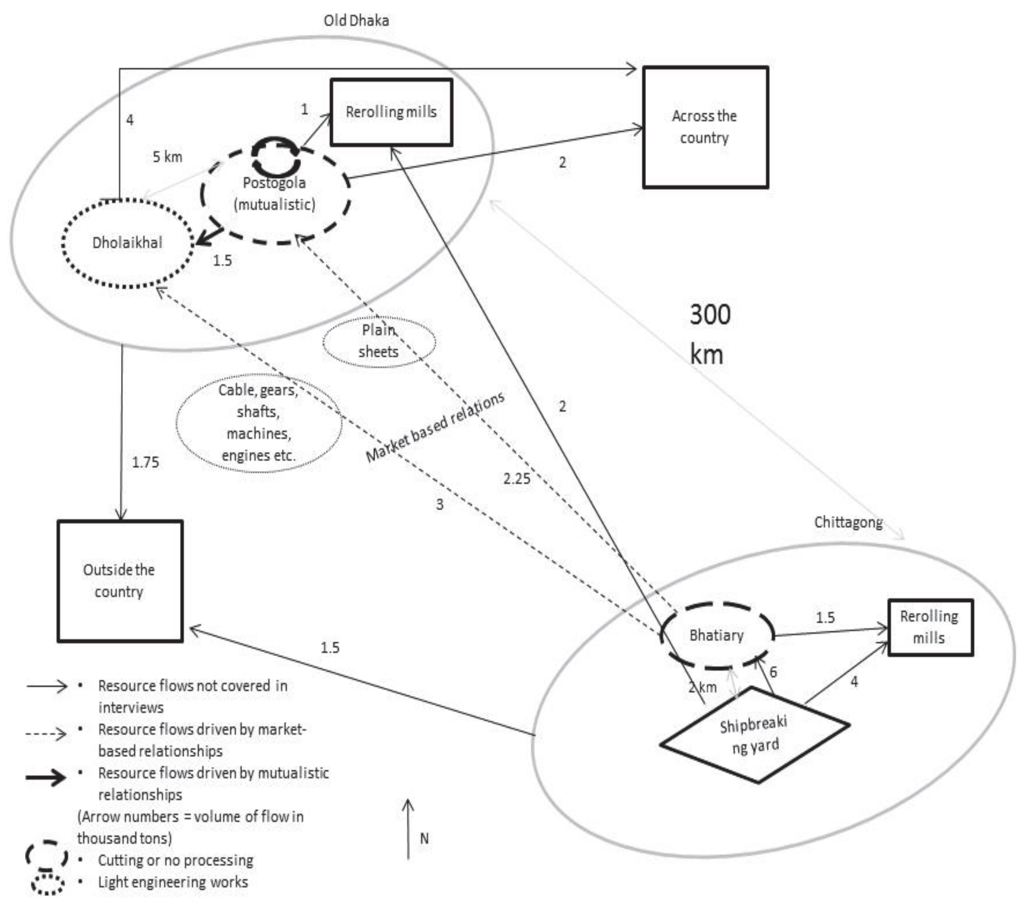
	Total	Business owners	Managers	Workers	Locals

Postogola	Long questionnaire	20	10	3	5	2
	Short questionnaire	35	20	4	10	1
Dholaikhal	Long questionnaire	8	2	0	6	0
Ship breaking yards (Bhatiary)	Long questionnaire	20	6	3	6	5

1.4 Results and Discussion

1.4.1 Resource distribution

Figure 1.2 shows the distribution of the materials recovered from the ships and the agents involved in the flows. For example, the Bhatiary markets focus on engines and parts, kitchen equipment and furniture salvaged from the ships involving traders who buy and sell the scraps across the country. Nonferrous scraps such as furniture, boards, lifeboats, kitchen equipment, and domestic equipment (such as light fixtures) are directly sold to end users through the small and medium enterprises with minimal or no processing in Bhatiary, Chittagong. Ferrous equipment such as metal sheets, engines, gears, cable, compressor and crank shafts are processed through multiple agents at all three sites. However, only metal sheets are handled in Postogola; businessmen in Dholaikhal handle a variety of scrap. There are about three hundred businessmen in Postogola who buy and sell metal sheets but do not involve themselves in processing metal sheets directly. After the metal sheets are sold (to businessmen around the country), the buyer of the sheets will get their sheets cut down to specification by cutters in Postogola who have small shops where they wait to get cutting contracts from buyers. There are three rolling mills in Postogola (which produce rebar for construction), and the owners of those mills buy metal sheets from Postogola businessmen or directly from Chittagong yards. Businessmen in Dholaikhal also buy scraps from Postogola and make various final products including households utensils, automobile parts, engine repairs, and other machineries using their light engineering tools such as lathe machines, in addition to buying and selling the ships'



valuable parts such as engines, gears, cables, and other machineries (Gregson et al. 2010, Sarraf 2010).

Figure 1.2: Relative resource flows described by our interviews, with arrows denoting the approximate proportion of metal volume flow by weight (in thousand tons) based on an average ship of ten thousand tons scrapped at the yard.

The way the scraps spread across the country begins in the Bhatiary region in Chittagong (Figure 1.2) – an economic zone situated within 2 kilometers of the yards where most of the ship breaking materials are traded. The traders of the Bhatiary region buy all resources from the yards and stock them on either side of the road in Bhatiary. Businessmen often purchase scraps from traders (rather than directly from the yards) because each trader specializes in particular kinds of scraps, providing a valuable sorting service. Furthermore, yard owners only sell scraps in large, wholesale quantities; businessmen are more interested in smaller quantities and therefore can buy them by the piece from the traders. These resources include all kinds of scraps from the yards (e.g., pipe, gears, engines, furniture, paint, ceramics, asbestos, glasswool, cables, big tanks, railings, and toilet accessories) except the plain sheets that are bought directly from the yards in the most quantity by Postogola businessmen. Dangerous products such as asbestos are viewed as a resource, as the people use those materials in their home roofing. In Bangladesh, asbestos is still a socially acceptable material to use without special precautions, due to a low awareness level of its dangers accompanied with low living standards which makes these materials (regardless of their dangers) a necessity when less-dangerous materials are too expensive.

Almost all businessmen in Postogola and Dholaikhal depend solely on the scraps from the Chittagong ship breaking yards generally (or Bhatiary specifically) for their raw materials. Plain sheets go to Postogola; half of those are directly obtained from the yards and the rest through the Bhatiary traders. The other resources are traded from the Bhatiary region directly to Dholaikhal in Old Dhaka city, or to the rest of the country, or abroad. Some metal resources (including plain sheets) are also sent to the rerolling mills in other areas of Chittagong and Dhaka to make rebar for construction. Gregson et al. (2012) refrained from describing this relationship as a symbiosis; instead, they described it as a territorial agglomeration involving thousands of actors transacting in a geographic location (Gregson et al. 2012). Although Gregson et al. (2012) confined itself to the recycling cluster in Bhatiary, we observed that this network extends to other clusters in Postogola, with similar industrial and social features as in Bhatiary.

To demonstrate the extension of a recycling cluster in Old Dhaka city, we have conducted material flow analysis. Figure 1.2 represents approximate metal flows across the country and abroad using responses, especially from the ship recycling yard managers and traders from the Bhatiary region. While opening his transaction files, a yard manager said that “almost all traders of that scraps dealings are from Bhatiary.

They sell them across the country." When asked where they sell their scraps, one of the three traders present in the shop in Bhatiary said that "we sell across the country, but mostly go to Postogola and Dholaikhal and also the owner of rerolling mills both here [Chittagong] and Dhaka." Several businessmen were asked how much tonnage in metal sheets comes every day into Postogola, to validate the information from the Bhatiary traders. Their responses ranged from 600 tons to 1000 tons a day. One said, "Well, this is business, we cannot say it in figures, as this varies largely. One day I sell huge and then, in next two days, almost no business. But we bring almost twenty five percent of the scraps." About half of the total scraps are sent to rerolling mills. The remaining material is distributed across the country first to Bhatiary and then to both Postogola and Dholaikhal. Essentially, the difference in activities in Postogola versus Dholaikhal is dictated by the engineering skills that are used to make final products. While metal sheets are cut as per the customer's specifications in Postogola, Dholaikhal businessmen have higher metal processing skills that are passed down through generations.

Postogola and Bhatiary businessmen profit mainly from buying and selling, however there are a few shops that process scraps. For example, plain sheets are not processed in either Bhatiary or Postogola regions except for cutting them into smaller pieces; these smaller pieces are sold to enterprises in Dholaikhal to be made into final products. Some sheets go to the ship building dockyard to make or repair launches, steamers or boats. Sheets that are low graded (i.e., not intact enough to repair ships or to make end products) are sold to rerolling mills for recycling.

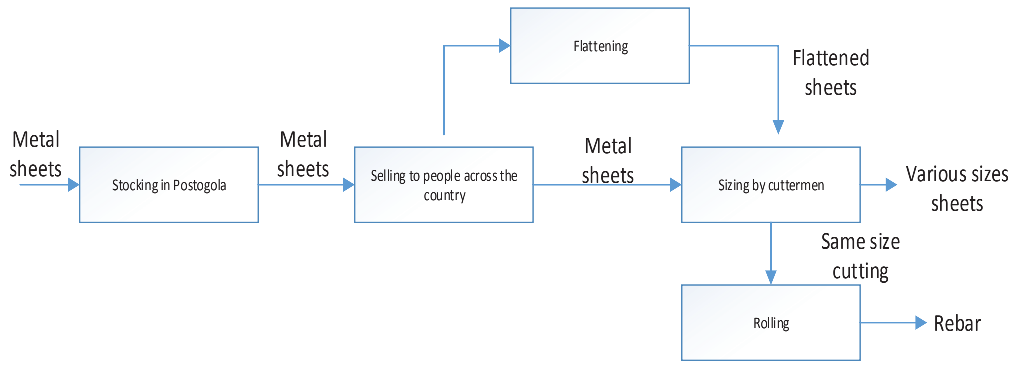


Figure 1.3: Resources processing in Postogola

Figure 1.3 describes typical resource processing in Postogola. Metal businessmen bring resources to their area from the Chittagong yards. The primary scraps are metal sheets that are repaired by certain business firms who have repairing machines that function mainly to flatten the deformed sheets. There are rerolling mill owners who buy low graded scraps from the metal sheets businessmen. Rerolling mills in the area buy scraps from firms to melt and mold them for construction purposes. Cutting firms cut the sheets into the required size. While they are sold, cutter men are called on to make the buyer’s desired sizes and shapes. Workers’ pools contract their labor to buyers for loading scraps to buyers’ transports. Thus the Postogola region forms a network of various firms centering on the inputs of metal sheets from Bhatiary.

The firms in Dholaikhal make final products by applying light engineering techniques using different lathe machines, for products such as bolts, nuts, spades, scissors and other tools. One interviewee said that "the final products made from the plain sheets are more durable than those made from raw iron, as these international ships are made up of high quality iron sheets." The resources that are reused for these final products represent up to 50 percent of the total metal resources of a ship. Only the low quality and rusty iron scraps are left to be sold to the rerolling mills to produce rebar— these resources represent the other 50 percent of the total metal resources. This separation of the materials based on the quality of the metals follows the concept of technical nutrient management (McDonough and Braungart 2010).

1.4.2 Historical (spatial and temporal) embeddedness

Interviews of the traders of both Bhatiary and Postogola indicate that spatial and temporal embeddedness with its historical components of gradual evolution influenced these communities' dependence on the metal resources from the ship breaking yards (Table 1.3).

Table 1.3: Comparison of spatial and temporal effects of resources

Type of embeddedness	Components	Bhatiary zone	Postogola zone
Spatial	Distance from key resources	1-2 kilometers	300-350 kilometers
	Geographic position	Near coast	Near a river

	Geographic extent	10-15 kilometers	3-5 kilometers
Temporal	Causes of involvement	Increasing scraps supply	Declining resources supply
	Industry start	With few people	With few people
	Previous professions	Different	Same as metal working

The Bhatiary economic agglomeration evolved gradually with the increasing flow of scrap resources from the yards. The original professions of the people in Bhatiary were agriculture, fishing and forestry (Gregson et al. 2012); the scrap recycling industry started about three decades ago, when some left these professions to engage in metal scavenging. According to an elderly resident of the region, no one in Bhatiary was involved in ship breaking activities in 1978; all were fishermen who harvested in the coastal fisheries. He said that he "along with 'K' (owner of one of the biggest rerolling mills in the region, called KSRM) and 'Kh' (another big name in the steel industry called AK steel) started to buy ships that were beached over there." (He was pointing to a place about one mile away.) "All of the traders you see here are from among the families of me, K and Kh," he stated. One trader remarked that metal scraps trading "is a huge opportunity for us and an easy process to deal with. We are lucky that this business developed here. I buy from here and stock them in Bhatiary. We even export stainless steel, copper and other metals abroad." There is evidence that this shift in professions was not just a pull towards new resources, but also a push as the local fish stocks deteriorated. A fisherman in the locality said that "Nowadays, the catches are declining, not like those in 70's and 80's when we used to catch a lot of different fishes. Lots of fishermen have left fishing." The decline in fish catches are often attributed to ship breaking activities in the regions by local non-governmental organizations (Hossain and Islam, 2006).

At the macro level, the failure of the state-run primary steel production to meet high demand, the weakness of the Bangladeshi currency, and the lack of environmental regulations have also been identified as driving factors of the industry. At the micro level, the entrepreneurial culture of the business cluster in Bhatiary is also an important factor in addition to the supply of metal scraps in the area (Gregson et al. 2010). Gregson et al. (2010) mention that the youth in the region dream of becoming a big ship breaker one day, and that their business acumen and growth is based on making new products from low grade ship metals. One such trader who provided access to one of the yards said, “I want to buy ships one day. I used to work in the yard and started doing business with this. Now I am contacting with one who has money. Look, I know each and everything in here and I’ve been in here for ten years.”

As for Postogola, the involvement of the locals in metal scrap recycling predated the official shipbreaking industry, starting with a river port on the Buriganga River about four decades ago. According to one elderly interviewee:

> In the 1970s, two or three people scavenged the iron pieces around the area and sold them to the nearby market. Eventually, the port activities stopped as the rivers were narrowed by the wastes and land grabbing of the politically connected industrialists. Launches, steamers and boats started to be

dismantled by people involved in scavenging at a small scale. Later, these early scavengers became the masters of the metal recycling business in Bangladesh [and thus benefited from their early entry]and started to import

scraps from Chittagong as their business grew.

Interestingly, these scavenging activities were done by the siblings of a family who later became millionaires. Since then, the businesses have been adopted and expanded by their immediate family members. The evolution of this business as mentioned in the above statement provided a positive feedback (as family connections grow, so does the business), increasing the flow of scraps toward Old Dhaka. Another interviewee from a neighboring shop said, "This big name has also built a rerolling mill here. He did a wonderful job and made mountain high money."

The spatial dimension of the growth of the industry is important too. As one interviewee remarked, "When the river activity started declining and fewer launches, steamers and boats were there to dismantle, the metal workers desperately started to look elsewhere for the metal resources that suited their skill and expertise." Thus, the coincidence of their demand for metal resources and the increasing scale of such resources available in the Chittagong yards established links between the businessmen in Postogola and the traders in Bhatiary. The individual or group responsible for establishing this link is difficult to determine. One elderly interviewee mentioned,

I am the only person [who] knows how this recycling zone expanded here, no one knows about it. The owner of the rerolling mill here who was a scavenger

> first went to visit one of his friends who lived near the ship recycling areas and informed him about the possible sources of scraps. Afterwards, that friend became a middle man to buy scraps and truck them to Postogola. Then, he brought two of his brothers into the business, realizing that he would need them as the business grew. That's the start.

This interviewee was the only one who knew these details, however many of the other interviewees later came to know the identity of this first scavenger. Thus, two important factors drew the resources from the Chittagong ship recycling yards to Old Dhaka: the expansion of family businesses and the deployment of relatives as intermediaries.

The essence of temporal embeddedness is that it locates the gradual expansion of activity over time and provides an explanation of the provenance of a certain activity to allow for the identification of a causality in the process (Dacin et al. 1999). While spatial and temporal embeddedness is often neglected in the study of embeddedness (particularly in industrial ecology case studies), here it is evident that the historic engagement of the metal scavenging activity of a community led to the search for such inputs, drawing resources towards them to sustain their new profession.

1.4.3 Cognitive embeddedness

Cognitive embeddedness refers to the relationship between mental states of two individuals in terms of how closely they think alike. An individual's mental faculty is shaped by the "short mental distances" of actors as they interact (Boons and Spekkink 2012). The maintenance of these short mental distances among actors creates a 'habitual action pattern' using heuristics in their day to day decisions (Boons and Howard-Grenville 2009). Short mental distance is evident in the mutual dependences among businesses in the metal recycling industry. The core business dealings are limited within the family ties of the businessmen. One interviewee remarked: "I do not go to anyone for money except my family members; I go and take small amounts of money; he [one of his family members in neighboring firms] also comes whenever he needs." However, some also have close ties with a few non-relatives, as another interviewee said:

> "I am working here as manager; sometimes my boss asks me to borrow some money. I go to those who I have good terms with, I do not go to those who I do not know. I am not tied with any family relations since I am here from other places, working here for four years. Usually, they also come to me to borrow money. It does not happen that someone is refusing even if he had money. This happens as we do this for a long time. This has become our habit."

Another interviewee said that “Businessmen here do not envy others. We think that if someone has more transactions, I will have more tomorrow. Even some come to his fellow businessmen and say, ‘I cannot sell this product, please sell this for me’.” The dynamics surrounding trust for borrowing and lending money and resources illustrate the reliance upon short mental distances for business transactions.

Even an individual’s desire to handle metal scraps is rooted in how the actor conceptualizes the resource (Boons and Howard-Grenville 2009); pride and craftsmanship were commonly mentioned themes. One interviewee stated, “This is our business, this makes us dirty. We live through dust and cranky sounds; but that’s fine. This gives us money, food and living too. We do not feel that this is dirty, we have been doing this for a long time.” Ashton and Bain (2012) described a similar dynamic as “short mental distance” when they measured factors that encourage people to handle wastes. A shop manager said, “Like you, many big engineers come from university, mechanical engineers, are you an engineer? They like our skill and ask us how we cut, process and make products. We can make things that the brand product can’t make, yet very cheap.” Another interviewee said, “When a passerby passes, they see in fascination what and how we are doing things here.” These statements also demonstrate that without such cognitive attachment towards the waste metals, the business would not grow and, consequently, metal would not come here – evidence of an individual cognitive value that bonds them to their business and continues to direct material resource flows.

The influence of cognitive embeddedness is also illustrated through the recruitment of family into the industry, maintaining the necessary trust among the businessmen in Postogola. Different from “short mental distance,” the reliance upon family indicates that these linkages not only require actors to share an outlook, but also require relationships based on trust. One interviewee commented upon the heavy influence of family traditions in this industry: “My ancestors were blacksmiths. I have seen them producing spades, knifes, axes and other domestic products from the discarded metals collected from the locality. I learned this when I worked in my elder brother’s factory for ten years, and then started my business in 2002 independently.” Another interviewee described how he became involved in the metal business: “Two of my four brothers are in this work. My father was also involved but in smaller ways. My cousin plays an intermediary role in the business, focused on maintaining contracts and managing financial transactions with the ship breakers in Chittagong.”

Businessmen expect their sons to take over if they do not continue on in higher education, and indeed many older businessmen did not see value in higher education. Regarding the educational status of his elder son, an elderly businessman said, “What is the need of his kind of study? He won’t get a job. I want him to see my business and learn as early as he can.” Although he was expressing his frustration over the standard of his son’s education, he hinted that he would be happy to see his son in this business for his future financial security. Some respondents do not value higher education for their children, as they typically do not get jobs related to their education level, or those jobs earn less income than what can be earned in the metal recycling industry. In addition, these types of jobs (gained after higher education is completed) were seen to be more restrictive and offering less freedom than metal recycling businesses. In this social setting, it is the business activity which makes individuals equal in status; interactions vary by their occupational involvement. People in similar professions are far more likely to interact than people of different professions – for example, metal businessmen tend to interact less with teachers, even sometimes they undermine teaching jobs and boost their business (Jahan et al. 2011).

1.4.4 Structural embeddedness in Postogola

Structural embeddedness relates to the interpersonal relationships which influence the economic actions of a particular society. In the Postogola case, there are two types of social networks: one among the businessmen in the metalworking areas, and the other involves interaction between the Postogola businessmen and the traders in Bhatiary. The network connections between the Bhatiary traders and the Postogola businessmen ensure a constant flow of resources to Postogola. Here I recount the perceptions of the people of Postogola and Bhatiary regarding the pattern of their relationships.

Uzzi (1997) describes two types of transactions: one is an "arm's length" transaction which is atomistic in nature and happens once in a lifetime; and the other is an embedded tie that is mutualistic in nature and happens again and again. When asked “How does one businessman trust another in terms of the price he gets from selling particular goods?” an interviewee from Postogola responded, “This is normal. They know that no one is going to lie, because he will also take this favor from me. So it’s equal, none loses.” This sense of reciprocity and repetition of similar dealings provided a shared expectation among the businessmen in the Postogola area. When asked, “How did these good relations develop here?” the same businessman said, “Here everyone sees everyone, we spend almost 10 hours in 24 together. When dawn breaks we see people here, the same people, and the same discussion.” This reflects Granovetter’s (2005) observation regarding a common unwillingness to profit from within a community. The use and availability of non-economic resources including “selling other’s goods, going to buy others’ goods for customers and borrowing money from others to purchase goods” embodies their shared meanings and business logic in which they think of themselves as fellows and that they are doing business with others, not among themselves govern their actions (Biggart and Guillen 1999).

This societal strategic advantage dissipated beyond a certain boundary of family- and friendship-based interactions. An interview with one old businessman of Postogola illustrates this point:

Interviewee: “I do not go anywhere, no, no one else goes anywhere. They do not have time. See, once you come in the morning and go back home in the evening. Where is your time?”

Interviewer: “Do you go to the homes of businessmen?”

Interviewee: “Yes, we go to home of one or two of our businessmen who are very close.”

Interviewer: “Who are those who you consider as close?”

Interviewee: “My elder brother’s family and one of my school friends.”

This interaction illustrates two points. First, there are close relationships with familial-connected people and with people whom they have known for a long time. Second, they have little time to have broader involvement in their community beyond their business. Regarding the first point, we found no one who had come to this business outside of family connections, within son-in-laws or maternal cousins beyond immediate family connections. Our interviews suggest that within the same stage of the value chain, businessmen generally maintain a very small group of close ties consisting of two or three people (where “value chain” denotes steps in the production process starting from yard processing in Bhatiary to the Old Dhaka scrap processing businesses). These small groups are connected to the rest of the businessmen through the weak ties generated by buying scrap or items in the market, where prices and available inventory are general knowledge:

> Everyone knows what today’s prices are and nobody is going to ask for higher prices. When we buy, we buy at a market price and that price is same for all of our enterprises and when we sell, we sell almost at the same price with others.

> The only difference is how the customer is choosing which metal is good or bad. This is the customer's idea about quality, we do not think about it.

This homogenization of transactional content brings stability to their businesses, reflecting the strong-tie and weak-tie argument of Granovetter (1973). While maintaining a tight relationship with a few family-connected businessmen, the people have a thin relationship with all of the other businessmen which enable them to be included in the general information stream about the daily changes of the resource prices. In Postogola, most enterprise offices were occupied by no more than three business people – an example of small-group strong-ties in the society – illustrating that strong ties do not occur among the large groups (Granovetter 1973, Burt 2009). However, they also develop and maintain weak ties with the businessmen to maintain the flow of information, representing the usefulness of weak ties in the Granovetter (1973) argument. In Postogola, the small path distance of the actors can be understood from the geographic size of the area. Although the monetary transactions amount to millions of dollars, the area where actual business occurs is only 3-5 square kilometers. While all, without any exception, stated that they do not borrow or loan money from other businessmen except from family or very close associates, they admitted to buying metals from other business people when they did not have that material to sell to customers.

There exists no regulatory framework that provides adequate oversight of these businesses, despite the growing attention generated by newspaper articles about this industry and skills associated with it, as well as the support needed to expand the industry (Laskar 2007; Gazi 2015). Government officials (National Board of Revenue) sometimes visit these areas to ensure that taxes and utility bills are paid. Indeed, several interviewees were reluctant to participate in an interview, fearing that we might be from the government-appointed tax collectors, indicating the lack of communication between government officials and the businessmen.

However, there is evidence that the community places more trust on reciprocal relationships within the community than those outside of it – a behavioral differences observed based on the type of transaction. The problematic economic dealings of the Postogola businessmen with Bhatiary traders, mostly arm's length ties (Uzzi 1997), are evident by the businessmen's unwillingness to provide contact information of their intermediaries in the Bhatiary. For example, among the 20 people interviewed, 6 gave their intermediaries' contact information. Four others have said that they did not use the same contact intermediaries anymore, while some others mentioned that they dealt with a bank that makes dealings more reliable. In one interview, a businessman of Postogola said that "I have some debt to one of the people and that I do not want to give you their contact information." Another interviewee from Postogola asked, "What will you do with this number? I owe some money. If you contact him and tell him my name, I will be in trouble." Another interviewee from Postogola said that "since we started business, we used only one trader for purchasing our goods. We get good quality metals once we take from the same person. Also, sometimes, we can give half money and the rest half we pay after sale; sometimes we go to others in case he does not have that metal."

However, the view of the Bhatiary traders who were interviewed reflects market-based relations with Postogola traders. One interviewee stated that "we do not know anyone, nor do we need to. We sell scraps to anywhere in Bangladesh either through Banks or direct cash. When someone orders, we send their products, otherwise we do not. We do not risk our business." When asked how they maintain communication among each other for buying and selling goods, one interviewee said that "the businessmen call when they need scraps. Once they get good quality scraps, they call next time". The relationship between the different nodes of the networks in Postogola and Bhatiary is impersonal. The Bhatiary traders deal with businessmen in Postogola simply due to their location, as Postogola is famous for scraps businesses. As one interviewee stated, "once someone calls from Postogola, I try to maintain the business trust in terms of quality metals as I know that they are our potential customers". This illustrates that across stages of the value chain and geographic regions, the trust-based transaction seems absent and market-based relations predominate, unlike within stages of the value chain where the relations are more mutualistic and trust-based, developed through years of interaction (Figure 1.2).

While there is an obvious advantage to maintaining good relations with traders, it is evident that there are instances of misusing the opportunity. The missing or unstable bonds between the businessmen in Postogola and traders in Bhatiary do not hinder the resource flows toward Postogola. This suggests that the strong cultural embeddedness, reinforced by the intergenerational skills and social identity in Postogola regions, guarantees the continued supply of resources.

1.4.5 Cultural embeddedness

Institutions, customs and social norms contribute to the formation of a particular cultural identity for individuals, and technical knowledge can be transferred across generations and is sustained as social memory (Arrow 1994). For some, business logistics are aided by family ties while for others, this is highly inappropriate and instead more formal financial institutions such as banks are used (Boons and Howard-Grenville 2009).

In the 1980's, Postogola was a city center. Gradually, administrative units, markets, hospitals, schools and parks have been constructed in a new place outside of Old Dhaka city; this new region has assumed the name "New Dhaka.". The transfer of the central activities to New Dhaka left the Old Dhaka community locked into traditional activities, which culturally separates this community from the emerging modern culture in New Dhaka. Although its uniqueness has contributed to an identity of localness - called '*Purono Dhakayya*' (old Dhaka people) of which they are proud, the Postogola area is considered a “sacrifice zone” (Hedges and Sacco 2012) for polluting metal-related industrial activity.

Unlike the businessmen in the Postogola, Dholaikhal economic agglomerations are famous for their high technical skill for manufacturing any kind of automobile parts using relatively simple lathe machines (Laskar 2007), even though none receive formal education (Figure 1.4). One interviewee said, “Many engineers come to see us. They ask us many questions. They are surprised that we know these skills. Even for their thesis or development of parts of vehicles, they come to learn from us.” One interview reported in a newspaper article mentioned the businessmen’s ingenuity and pleasure from innovation:

> I still remember how delighted my father was when he put together a small car engine all by himself. These parts [sold here] might appear to be insignificant in the eyes of modern science, but they mean a lot more to common folks like us (Laskar 2007).

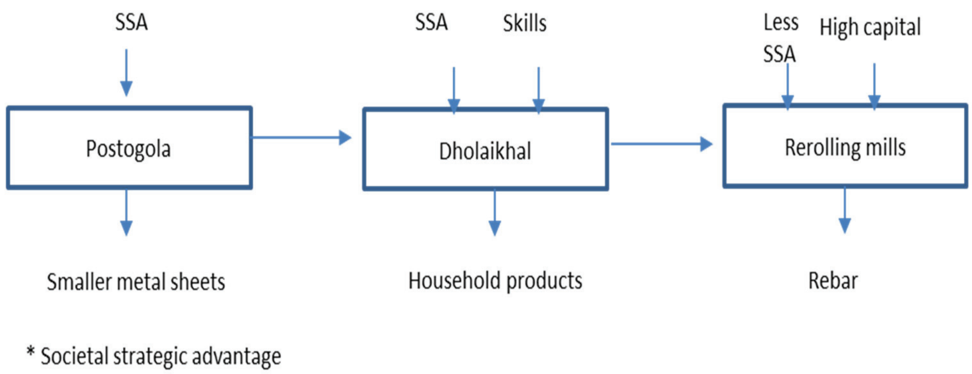


Figure 1.4: Different level of social ties relative to the level of complexity of the process involved in Old Dhaka.

When asked why the metal workers do this kind of work, they responded that they can do things that others cannot do. While a technician used a big lathe machine to cut a metal piece, he said, "You came to see us, that's okay. You know, how we take the measurement [while he was lowering down the face of the lathe machine], we do not use a scale. We have an idea, and our eye makes such a measurement for us. I have been doing this since I was eight." The sense of pride in this skill level provides an identity or "insider effect" which makes this work satisfying and bonds the tradesmen together (Akerlof and Kranton 2005). In Postogola, this insider effect is obvious. When they say, "everyone sees everyone," "none envies others," "having freedom" and "feel proud of our skills," these feelings bind everyone in societal norms that promote business relations and happiness (Figure 1.4). These norms are also promoted by the formation of an association in the community. One interviewee said that "we save money in the association, it loans money when someone needs it out of the savings. We close our shops when someone dies or is injured seriously, all take part in funeral, and association arranges picnics and other events. We always work together."

However, the value of the association for regulating social norms was not consistent across all interviewees; older interviewees were less supportive. One elderly tradesman (approximately 70 years old) said, "We do not go there [to the association], what's the point? They come to take monthly fees from us, provide some chairs and tables there, that's it." He continued that "on occasion of internal conflicts, we attend the meeting" but "that's very minor and very rare that people go there for reconciliation." A younger businessman (about 35 years old) said, "Yes, we have an association and it works fine. We have a constitution and we take care of how the businesses are going. We sit together and discuss issues. If we do not do this, business will not go forward. There are always issues with payment with the external businessmen in Chittagong and we resolve those." This difference of interaction perspectives based on the age level has not been explored in depth or reported in previous work. However, the differences in the ages of the interviewees and their experience with the industry association are very interesting, and suggest that the network is evolving. Whereas older people did not need an association since they knew all of the players, as the industry has grown there has been a growing need for a coordinating mechanism and interest group to act on their behalf. Thus there is an increase in the formalization of the business, through organizations such as trade associations and banks.

The community builds and maintains cultural embeddedness through a "learning by doing" tradition that stabilizes their interactions and upgrades the importance of these interactions from a personal to a societal level. Even though the interactions are personal (one-on-one), the news of a failure of a personal interaction is quickly dispersed to all other business people. This reduces the internal cost of risk and effort, as the risk involved in a market system where a transaction happens once in lifetime between two self-interested individuals is checked by a rigorous process of finding trustworthy partners, drawing rules and regulations, enforcing the contracts, etc. For example, the Postogola region is highly regarded as a society of metal sheet businesses, and any transaction within this region due to their historic recognition and reputation minimizes opportunistic behavior and risk (Granovetter 1985, Rooks et al. 2000). More importantly, although they have separate offices for each business, the metals sheets are commonly stacked in an open field with no barrier or fence separating the piles. This reflects the exclusive understanding among the businessmen in the area with their metals.

1.4.6 Interactions among dimensions of embeddedness

Table 1.4: Phases of embeddedness and to resource flows (from Domenech and Davies 2011)

Phases	Characteristics	Old Dhaka case study
Emergence	Lack of key component	Shortage of scraps source
Probation	Decrease risks and expands linkages	Preexisting experiences of metal processing

Development and Expansion	Referrals and recruitment	Family recruitment

The Postogola industrial cluster went through an emergence process through the lack of key metal resources, causing businessmen to seek out external sources (Table 1.4). In the probation period, the continuity of supplies was sustained by the pre-existing cognitive and cultural embeddedness which generated tacit knowledge and a pride associated with metal recycling activities. The development and expansion phase is not yet wholly evident, as the furthering of networks has not occurred across stages of the value chain (particularly between Postogola and Bhatiary), due to some abuses of transaction trust beyond their community and the lack of third parties who could restore trust. Banks may grow into this third party and intervene in this lack of confidence by providing a neutral ground for transactions and trade, but which would be formal and disconnected to the conditions of embeddedness.

In this case study, we see that although the structural embeddedness is intense (represented by personal ties within the same stage of the value chain such as ties among the Postogola businessmen), across the stages of the value chain between Postogola and Bhatiary, such ties are absent. In Postogola, the cultural and cognitive embeddedness provides an adequate foundation for the localities to handle and process materials and maintain the profession across generations. This intense embeddedness in these two dimensions compensates for the weak pairwise ties in the structural embeddedness dimension across the value chains stages, in the form of mutualistic relations among Bhatiary traders and Postogola businessmen. In this situation, long term reciprocal relations and the accumulation of experiences with cooperation within a stage facilitates non-family-based ties, and contributes to the development and expansion of the recycling network (Domenech and Davies, 2011).

Table 1.5: Interviewee quotes linked with types of embeddedness

Example statements	Theoretical terms	Dimensions	Effects
" few scavengers" "lucky to have this" "money exchanges" "I borrow money"	Early adopters Long term reciprocity (Nadvi 1999 b)	Spatial-temporal	Facilitate resource flow Community feelings
"brothers, father, friends" "freedom" "habit of exchange" "do not envy others"	Family ties (Ashton 2008)	Cognitive	Entry to business Internal business logics Mutual understandings
"no price hassles among us" "help selling others goods" "owe to Bhatiary traders" "I take from one trader in Bhatiary"	Embedded ties in Postogola Networks with Bhatiary Social ties (Boons and Spekkink 2012)	Structural	Reciprocity Non redundant information flow
"meeting once a month" "no fence or boundary among metals of different entrepreneurs" "save money "	Association ties (Dacin et al. 1999) Social memory (Nadvi 1999 b)	Cultural	Resolve internal collision Collective skill connects resources Societal competitive advantage

”do not require scale to cut, can manage by my eye” “closes if death or injury” “we all do business, all equal”		Promote collective sympathy

Table 1.5 summarizes how different aspects of social embeddedness are linked with metal flows; some frequently used quotes are used to illustrate these aspects of embeddedness. The spatial- temporal dimension is directly linked to the flow of the materials, whereas the other embeddedness aspects ensure other mechanisms that maintain these flows. For example, internal business logic and the culture of scrap-oriented skills are the products of cognitive and cultural embeddedness that maintain the demand of such metals flow through the areas (Table 1.5). Cohen-Rosenthal (2000) stated that maintaining sustainable networks for years among internal and external groups surrounding business exchanges remains an important challenge for industrial ecology:

> Shifting by-products from one place to another is not hard – making them safe, valuable and economical is the real trick. The resource to be handled through manageable transactions --- it has to obtained, transformed, transported, sold, and then reintroduced back into productive reuse. Hence there needs to be strategies to assure the most economical approaches to the collection and

distribution of potential products and byproducts. (Cohen-Rosenthal 2000, p.252)

The layers of ties in the systemic recycling of metal scrap, in this case, are “strategies” that established and evolved to form a chain of series exchanges coupled with value addition in Old Dhaka city.

1.5 Conclusions

Similar to previously reported cases of successful industrial clustering, business relations have developed in Bangladesh based on a delicate balance of business competition and tight knit social ties (Nadvi 1999b). In this society, some of the relationships within the network are more socially embedded than others (among same stage vs different stages of the value chain), while others are more clearly based on market transactions. This provides a trustworthy platform within a small group and maintains broader information and resources flows throughout the trading regions. The small group strength originates from their recruitment of family members whom they rely on to maximize the benefits of strong ties. At the same time, a broader group has developed on the basis of the weak ties. These layers are strengthened from their observations of daily dealings in the business such as common buying, customer/supplier relations, shared commuting, human resources recruiting, internal vs external information systems and by-product connections.

This case study illustrates that the Postogola industrial cluster was made possible by an existing cognitive attachment with the metals – a valuable condition for the development and expansion of the industrial networks as noted by Domenech and Davis (2012). In Bangladesh, to some extent this process exists in other industries; one interviewee mentioned that "yea, we do cooperate with one another, everyone does, and this is how business evolves. You go to neighboring market, ask the business person. They do same way we do. Nothing extraordinary." This point necessitates the study of other communities in Bangladesh that may represent similar mutualistic industrial networks that could facilitate production of a successful industrial cluster.

This industry also utilizes resource efficiency through a self-organized separation of high from low quality metal resources. High quality metal is reused with minimal processing, while the low quality metal is recycled, melted, or rolled into rebar, maintaining a process that a rational management of scrap resources throughout the society in terms of its functional capacity (Chapter 2). This process assures the elimination of down-cycling (where high quality resources are mixed with low quality resources). A deeper understanding of the pattern of social relationships leading to self-organized resource separation by quality or value would be an interesting pursuit (e.g., Asim et al. 2012).

There are alternative explanations for our observations related to politics and proximity to demand. Due to the sensitive nature of the topic, political embeddedness was not examined, but political allegiances may influence relationships and outweigh family connections. Demand for steel in the capital city necessitates having a supply center around the core construction area where high demand for steel exists. New Dhaka is densely populated and several government attempts have been put in place to expand this city outwards. Outward expansion is required to construct modern buildings for households, offices and infrastructure for which metal rods, bars and other hard metal are needed. Old Dhaka city is a place that meets the needs of this emerging construction demand that is strategically close to the demand center.

The existing transportation infrastructure also facilitates the movement of metal scraps to the Postogola neighborhood. This city is situated on the Dhaka-Chittagong highway that makes the transportation of this metal from the Chittagong shipyards economically feasible. The Von Thunen-Mills model suggests that transportation cost and land rent are the factors that determine the production location of a certain kinds of products, although Krugman (1996) rejected this model as it explains spatial organization but does not govern the emergence of the central town that consumes resources from the firm. Further work might investigate how the scrap metal is distributed from the Old Dhaka community and how the embeddedness can be used to build a more systematic metal processing industry. Certainly the community draws resources for their own survival, but this does not explain how the network and linkage mechanisms were established by the family connections and social embeddedness of this community. Large re-rolling mills (for rebar) in Dhaka city use this network for their raw materials; a study of the rebar community may provide useful information.

Long term characteristics accompanied by sustained resource flow and economic benefit give the Old Dhaka community a solid identity of metal workers that is shared among the community members, and eventually becomes conspicuous to other communities. Social relations based on family membership played a crucial role for the original influx of the recycled metals into this community, and does so still. We hope this work emphasizes the favorable social conditions that are required to establish industrial recycling systems in a community and the crucial importance of these features for the long-term success of an industrial cluster.

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Chapter 2: Life Cycle Assessment of Steel in the Ship Recycling Industry in Bangladesh[2]

S.M. Mizanur Rahman, Robert Handler, and Audrey L. Mayer

Abstract

The ship recycling industry in Bangladesh provides necessary scrap metal for domestic steel products, such as rebar for construction. These recycled products may represent a dramatic reduction in energy consumption and ecological footprint when compared to production from virgin iron ore. I used a Life Cycle Assessment approach to evaluate the energy use and emissions, from the beaching of retired ships in Chittagong to the end recyclers (rerolling mills and light engineering shops) in Dhaka. The secondary rebar produced from the scraps saves 16.5 GJ of energy and reduces 1955 Kilogram (kg) of CO_{2eq} environmental emissions when compared to primary rebar. I also compare different unit operations of steel scraps processing to assess their relative environmental impacts including Global Warming Potentials (GWP), resource use in terms of MJ primary, human health and ecosystem quality – the latter three using IMPACT 2002+. Although considered sustainable in terms of energy savings

[2] This work will be submitted for review to the *Journal of Industrial Ecology*.

and greenhouse gas emission reduction, ship recycling has other adverse impacts on humans and the environment, as indicated by IMPACT 2002+ metrics. In particular, the use of gas torches for metal cutting and impacts of the rerolling stage rank among the highest of the processing stages in terms of GWP and impacts on human health. These results suggest that the gas torch cutting should be prioritized for improvements in the industry, and that the rerolling stage needs to be modernized through the introduction of more efficient technologies.

Keywords: Ship recycling, rerolling mills, life cycle assessment, resource use, carbon dioxide emissions

2.1 Introduction

The ship recycling industry has been an important industry for developing countries, especially for those nations that have no domestic iron ore deposits (Abdullah et al. 2013, Sujauddin et al. 2014). Up to 70% of Bangladesh's total steel production is from scrap metal feedstocks, all sourced from foreign ships beached along the coast (Abdullah et al. 2013). At the global scale, the ship breaking industry closes the loop on metals, converting retired ships into bars, billets, and rods for the construction industry, and small equipment and tools for homes and small businesses (Gregson et al. 2010). This industry can help meet broad sustainability goals since recycling the ships into new products helps avoid the environmental impacts of the extraction of virgin iron ore to make products, which requires high energy inputs and damages ecosystems (Yellishetty et al. 2011; Weisz, Suh and Graedel 2015). Steel has a long functional life span and recovers most of its value if it is reused or recycled. Globally, 86% of steel is recycled (World Steel Association, 2014). Since this industry recycles most of the retired ships to produce secondary steel, one would expect that the industry reduces the net energy requirements of steel products.

The ship recycling industry has a long history of migrating from developed countries to developing countries, mainly due to profitability and lack of regulatory oversight. Before the 1980's, ship recycling was concentrated in developed countries such as the US, Taiwan, Japan, South Korea and Hong Kong. Increasingly, the activity has been shifting to southern Asian countries such as China, India, Bangladesh and Pakistan (Gregson et al. 2012). Analyses of the possible drivers of this shift reveal the low attention to environmental pollution, very cheap labor costs and lack of labor rights, and high steel demand in developing countries as key factors (Gregson et al. 2012). The lack of environmental regulations may promote unregulated releases of contaminants into the local environment and reduce the expected environmental benefits of steel recycling relative to steel produced from virgin ore. In addition, the process of recycling ships without proper ports and containment is labor intensive and dangerous to workers (FIDH, 2002). However, these recycled metal products contribute to the reduction of energy use and emission control at both national and global scales.

However, there has been no systematic accounting for the reduction of energy use and environmental benefits derived from the recycling of ships in Bangladesh, from the initial recycling stages to final end products. Life cycle assessment (LCA) provides a comprehensive methodology to evaluate environmental impacts of a product or process over its entire life time (Klöpffer 1997, Finnveden et al. 2009). This approach involves cataloging inputs of materials and emissions at each step of the process, converting all life cycle inventory data to a consistent functional unit with a systematic application of environmental impacts aligned with inputs. The life cycle of the product includes the extraction of raw materials, processing of materials, manufacture, distribution, use, reuse or recycling, and final disposal (Craighill and Powell 1996). This tool can be used to: improve the environmental impacts of a single product; compare the relative impacts of different products; and compare different systems such as recycling versus waste disposal (Craighill and Powell 1996). I used LCA to compare the impacts of using secondary steel scraps recovered from ship recycling for rebar production with impacts of primary rebar production. This approach allows for the comparison of the relative environmental burdens across different stages of the rebar life cycle, for example to determine if the beached ship cutting stage is more environmentally damaging than the rerolling stages. In addition, I examine whether the production of rebar from recycled scraps is more environmentally sound than the reuse or light engineering processes of these scraps used in Old Dhaka to produce household utensils and small machinery. This study identified the damage potentials to the environment of each production stage and, to a limited extent, risk to human health (Deshpande et al. 2013, Hiremath et al. 2015).

2.2 LCA Methods

2.2.1 Study design

There are four phases to an LCA study according to the International Organizations for Standardization (ISO) accepted approach: Goal and Scope Definition, Life Cycle Inventory analysis (LCI), Life Cycle Impact Assessment (LCIA), and Interpretation (Guinée 2002). Goal and Scope Definition defines the system boundary and functional unit of the product within which the environmental impacts in terms of energy use and greenhouse gas emissions are assessed. LCI assesses all related inputs and outputs that the product consumes or releases over its lifetime. The inventory data collection for an LCA study utilizes existing databases such as Ecoinvent (Weidema et al. 2013), government reports, and other primary data. LCIA measures the magnitude of the potential impacts of the inputs and outputs derived from a product or process. During Interpretation, the results are analyzed in relation to the goal and scope of the product (Finnveden et al. 2009).

2.2.2 Description of Goal and Scope

Our goal was to compare the environmental impacts between secondary rebar production (produced from ship recycled iron scraps) and primary rebar production (produced from virgin iron ore). The functional unit was one ton of rebar produced at a manufacturing facility. The system boundary chosen for the secondary rebar started from the transportation of retired ships from their originating country and ended with the operations performed on scrapped plate in the rerolling mills for producing rebar in the domestic market. The equivalent system boundary chosen for the primary rebar production (comparison system) began with the mining of iron ore and ended with the hot rolling process to produce rebar. This system boundary enabled us to compare energy and emissions between primary and secondary rebar production. I also compared impacts among production stages of secondary rebar products to see which stage is the most environmentally damaging (to prioritize areas for improvement). Finally, I compared environmental indices between light engineering and rerolling processes in Old Dhaka, based on a one ton of product weight.

2.2.2.1 Secondary rebar from Ship recycling

Secondary rebar production from metal scraps is relatively straightforward and can be divided into seven stages (Figure 2.1). Stage 1 includes the transportation of retired ships from the originating countries to the Chittagong ship recycling yards in

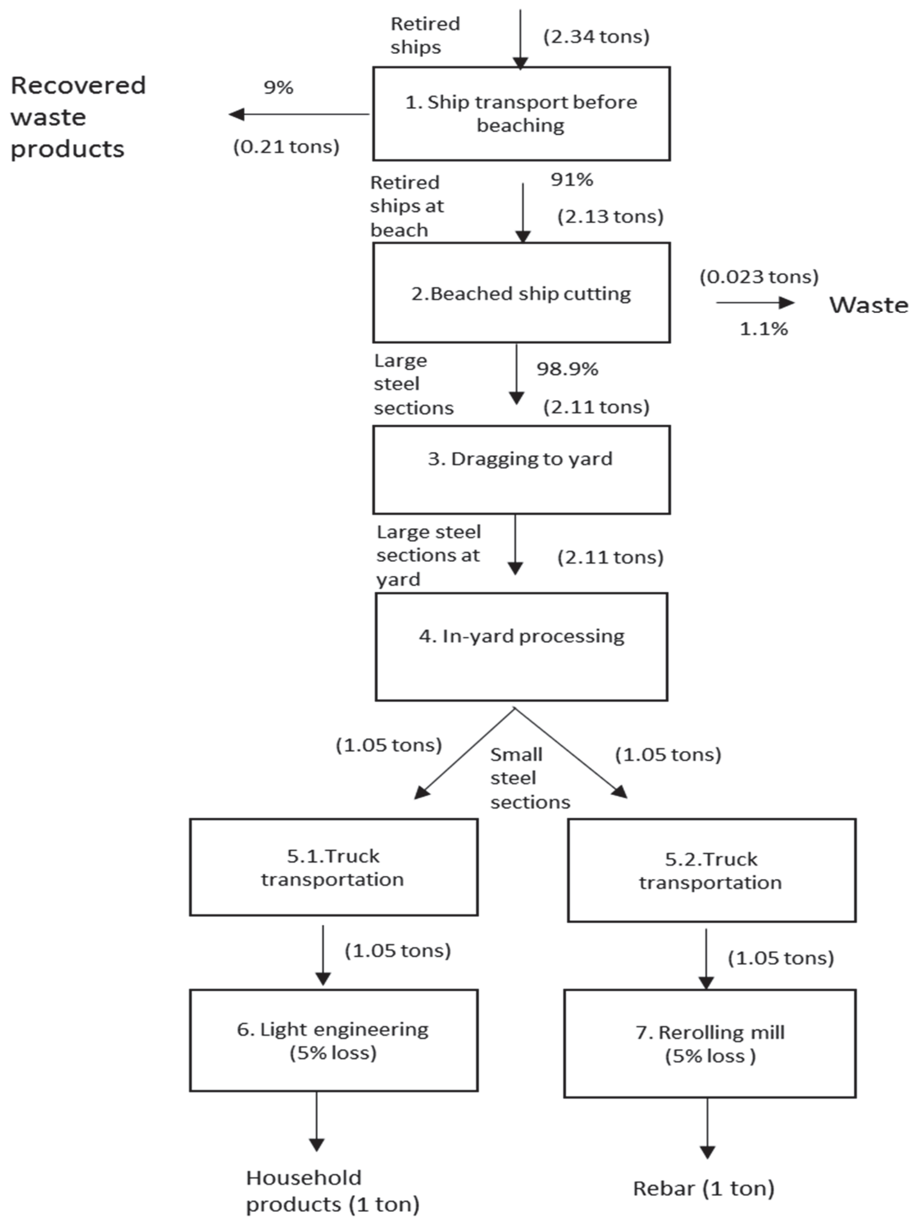

Figure 2.1: Process flow diagram of secondary rebar production in Rerolling mills and light engineering in Old Dhaka city

Bangladesh. Stage 2 is beached ship cutting that includes the cutting of ships into large sections. Stage 3 consists of fuel requirements due to dragging large sections of steel to the processing yard. Stage 4 consists of cutting of large sections to smaller sections that are loaded into trucks, followed by Stage 5 that considers the fuel requirements for transportation to the subsequent processing sites. Stage 6 consists of light engineering processing in Old Dhaka city and Stage 7 consists of rerolling of metal sections into rebar. Each stage requires fuel and materials for processing; some assumptions needed to be made to directly relate activities with more common processes that are well-described in the life cycle inventory databases.

2.2.2.2 Primary rebar from virgin iron

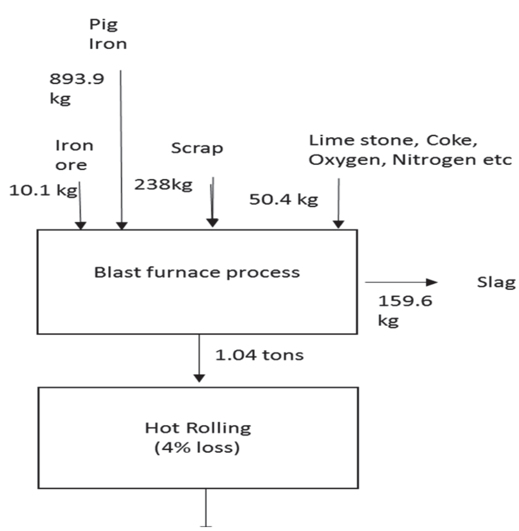

Figure 2.2 Schematic diagram shows primary rebar production from (virgin) iron ore

The process of making steel from raw (virgin) iron uses four main materials: iron ore, scraps, coal, and limestone (Figure 2.2). The preparation of raw materials starts with making coal into coke through a carburization process; then the pig iron is combined with coke with limestone, which is done in a blast furnace. Then, oxygen is added to convert this pig iron to primary steel in the blast oxygen furnace. The process of coal to coke and the process of iron ore to pig iron consume energy, even before the conversion of pig iron to steel. The data for this process were primarily adapted from Yellishetty et al. (2011).

2.2.3 Inventory Data Collection descriptions

I relied on data from both primary sources (interviews with local workers and managers) and secondary data sources (peer reviewed journals and websites) in addition to Ecoinvent data, which was used to best represent the inputs of materials and energy into the processes. To use our data with SimaPro modelling software, I transformed some of the Ecoinvent input data to represent the context of our study. Regarding primary data sources, the lead investigator interviewed key officials in the yard, including one yard manager, one cutting manager, one trader and one accountant. I also interviewed five cuttermen engaged in light engineering processing and one rerolling mill manager in Old Dhaka city. I conducted interviews in Bangla and translated them to English. In cases where multiple data on a same subject were available, I used the ones that were detailed, reliable and fit with the functional unit.

Data that did not have desired functional unit were transformed based on verifiable assumptions. In general, interview data were verified through comparison to similar data collected in different contexts.

For example, I transformed welding data to represent torch cutting by calculating the cutting length of the large sections in beached ship cutting and small sections in in-yard processing, based on the combination of interview and secondary data sources. The size of the ships in terms of length and weight was calculated from secondary data sources. However, data on weight and size of large and small sections were taken from the interviews. Thus, the cutting length for large sections and smaller sections were calculated as 1.7 and 4.9 meter per ton, respectively. The average thickness of the scraps was estimated as 12 mm. A welding item was chosen as a proxy for torch cutting, because welding and gas cutting are essentially the same process but with opposite functions; they release similar emissions and present similar threats to the environment and workers.

I accounted for the emissions from the combustion of Liquefied Petroleum Gas (LPG) and diesel by using stoichiometric ratios. I also constructed an item in Ecoinvent using primary waste data to reflect the impacts of ship recycling activities' discharge to air, water and soil. For this study, I have assumed that the weight and length of a typical ship is 10000 Light Displacement Tonnage (LDT) and 176.6 meters in length (Sujauddin et al. 2014).

2.2.3.1 Secondary rebar Data Collection Inventory

Here, I describe the data sources for each stage and how those data were used for Ecoinvent items.

2.2.3.1.1 Ship transport before beaching

I included the ship transportation impacts on the environment, as ships travel significant distances after the decision has been made to dispose of them (Chapter 4). Heavy bunker fuel is required for the retired ship transportation. I conducted a mass allocation based on estimates in Sujauddin et al. (2014) that suggested that about 91 percent of a ship is utilized further in the production chain. The remaining 9 percent includes the furniture, life boats and ceramics products – byproducts from ship recycling. One major assumption was that the ships were sailed from their originating countries when it was time for them to be dismantled (see Table 1.1 for distances used to calculate fuel). To calculate the amount of fuel consumed for transport to ship breaking yards, I estimated fuel consumption rate in kg per hour using the equation; .041 * (Gross tonnage) ^0.83. (Hulskotte 2014) (Table 2.2).

Table 2.1: Percentage distribution of retired ships to Chittagong, Bangladesh from the originating countries; adapted from Sujauddin et al. (2014)

Transportation distance estimation

Origin of ships	Percentage	Distance (Km)	Assumed Origin
Japan	44 %	4427	Osaka, Japan
European Union	26%	7164	Berlin, Germany
Korea	2%	3783	Seoul, South Korea
Others (US, China, etc.)	25%	13057	Washington, USA
Average	**100%**	**7151**	

Table 2.2: Data inputs in ship transportation before beaching stage

1. Ship transport before beaching		
Item	Amount and Unit	Comments/Sources
Container ships speed	600 km/day	Assumed minimum cost speed for retired ships; 25 km/hour, multiplied by 24 hours*, (Notteboom and Carriou 2009)
Distance travelled	7151 km/ship	From Table 2.1
Bunker fuel	0.0077 tons/tons of scraps	Fuel consumption calculation in kg/hour =.041 * (40000GT)^0.83 ; = 270.7 kg/hour.** 270.7 kg/hr*24 hr*7151 km/ship/1000 kg /ton/600 km /day/10000 tons /ship
*available at http://www.people.hofstra.edu/geotrans/eng/ch8en/conc8en/fuel_consumption_containerships.html		
** Source: http://cnss.no/wp-content/uploads/2014/06/fuel-consumption-web.pdf ; Figure2.2		

2.2.3.1.2 Beached Ship cutting

In this stage, cutter men use gas torches to cut ships into large sections; the maximum size is limited by the weight that the winch in the yard is able to drag. On average, a large section weighs 350 tons. Gas torches have two inputs: oxygen and LPG. I calculated the amount of fuel required for the ship cutting based on an interview with a shipyard cutting manager: "I do not have actual figures about how much fuel we use. Usually, one cutter man working about 10 hours uses one cylinder of LPG (12 kg) and 10-16 cylinders of oxygen; each weighs about 10 kg. Beached ship cutting requires only 10 cutter men who work only at day time. In about 45 days, I can cut a ship of 10,000 tons weight." The interviewee did not seem to have any incentive to either under or overestimate the data. The tentativeness of the estimation proves the fact that it is not their practice to document the quantity of the energy they use for the daily operations. Therefore, the fuel required per ton of steel accounts for 0.56 kg of LPG and 5.73 kg of oxygen (Table 2.3).

Table 2.3: Data inputs in Beached ship cutting stage:

2. Beached ship cutting		
Input	Quantity and Unit	Source/Comments
Dismantling time	4500 hours	10 workers x 10 hours x 45 days; Source: Interview
Oxygen	5.733 kg/ton of steel	13 cylinders of Oxygen per day each 9.8 kg, 10 workers for 45 days
LPG	0.56 kg/ton of steel	12.5 kg LPG/day, 10 Workers and 45 days

In this stage, I considered waste spilled to the coastal environment in three categories: emissions to water, air, and soil. While about 91% of each ship is recycled into steel products, roughly one percent of that 91% is waste that is discharged into the environment (Figure 2.1). The remaining 9% of the ship's mass is recovered byproducts that are excluded from the system boundary of this study. Although asbestos and asbestos-containing materials (ACMs) are resold in the market, I included them in our model as waste because handling them causes damage to human health (Table 2.4).

Two items were prepared in the Ecoinvent database. For one, I quantified waste discharged in beached ship cutting, based on data listed in Table 2.3, to model the environmental and health impacts of those wastes. For the other item, I converted the "welding" item in Ecoinvent database to a "ship cutting" item that incorporated the cutting length per ton of beached ship cutting based on the interview data. This ship cutting item was also used in in-yard processing and light engineering processing in Old Dhaka, modified to fit cutting activities in those stages. Fossil fuel combustion takes into account the burning of LPG and Diesel in the respective stages.

Table 2.4: Waste discharged into the environment from the ship breaking yard in Chittagong, Bangladesh; adapted from Hiremoth et al. (2015)

Waste Type	**Amount**	**Comments**

	(kg/ton of steel	
Ballast water	.001815	About 33 % capacity and contains 2-11 gm of petroleum per ton of water; (David, 2015)
Bilge water	5	Ref. Hiremoth et al. 2015; for Oil and chemical tanker, 25-50 tons per ship; Contains 16% of Oil *
Waste oil	0.05	Assumed 1% of oil that discharges into yard soil (Hiremoth et al. 2015)
	1	Assumed 20% discharges into water**;
PCBs	0.0002	(Hossain and Islam, 2006)
Paint Coatings	0.10125	Deshpande et al. 2013; Total beached ship cutting 1125 km-mm and;
	0.15	yard cutting 5625 km-mm (Hiremoth et al. 2015)
asbestos + ACMs	1.2	Sold, yet considered to include human impact caused by direct handling
Glass wool	0.011	Sold yet included
Landfill waste***	1.2	Assume 50 percent discharged shared from rust irons; and 50% of them to soil, and remaining to water
Incinerator waste****	2.66	Divided this into different emission discharge categories; discharges to air, water and soil
*Netherlands Inland water board, 2008 **"Nothing goes to waste... even the last drops of oil from the tanker's holds are drained and resold"(Hossain and Islam, 2006, p 11). ***The waste includes rusted irons, ceramics, incinerator ash, Fire ash, Broken Glass and cementing materials ****Includes Paint and Coatings, Oily sludge, Thermacoal, Polyurethane, Rubber gasket, PVC and Plastic waste		

2.2.3.1.3 Dragging by winch

In this stage, large steel sections are dragged to the yard by the winch. Winches consume diesel as fuel. I assumed based on interview data that working 3-4 hours per day, a winch can carry all of the sections of a ship weighing 10,000 tons in 45 days to the yard. Fuel required is 1.54 kg/ton taken from the interview data of 115-120 L/hour.

2.2.3.1.4 In-yard processing

In this stage, large steel sections are cut into smaller sections using gas torches. All kinds of steel sections are cut including machine parts, gears, stair railings, and metal plates, so that they will fit into the trucks. On an average, a small section weighs about 1.2 tons. In-yard processing takes place simultaneously with beached ship cutting. The LPG and oxygen required per ton of steel scraps are 2.81 and 28.67 kg, respectively. Magnetic grabs for loading plates into trucks are also used in this stage (Chapter 3, Figure 3.1). A magnetic grab requires 200 liters of diesel fuel to operate for 4 hours according to an interviewee. I doubled the fuel requirements as the grab works in two stages: in one stage it organizes the smaller sections, and in next stage it loads the materials into the trucks.

The cutting based emissions in this stage are different due to the fact that the cutting length is increased per ton of steel. The size of smaller sections (14 m^2) was estimated from interview data. Estimating the perimeter of small sections from the size of smaller sections obtained from the interviews, I calculated the number of small sections per large section, which was used to calculate total cutting length. The actual cutting length per ton is estimated to be 4.9 m/ton (Table 2.5)[3].

Table 2.5: Data input in in-yard processing stage.

4. In-yard processing		
Item	Amount (Kg /ton of steel)	Source/Comments
Cutting time	22500	50 workers, 10 hours and 45 days; source: Interview
Oxygen	28.67	Five times of beached ship cutting fuel consumption
LP	2.81	
Diesel (magnetic grab)	3.4	50 L/hr; 4 loading per 4 hour* 20-30 tons per loading; Diesel density .832 kg per liter

2.2.3.1.5 Transportation to light engineering shops or to rerolling mills

In this stage, trucks transport steel sections to the next processing units. Some materials go to Old Dhaka city where steel sections undergo light engineering work for making various household products and machineries. Other materials go to rerolling mills to produce rebar used in construction. Although light engineering shops and rerolling mills are both located in Old Dhaka, the majority of rerolling mills are found in other places that are ~200 kilometers away from Chittagong. I assumed a travelling distance of 300 kilometers to Old Dhaka and 200 kilometers to the rerolling mills.

[3] Along the width, three small sections of 2.1m can fit into a large section of breadth 6 m. Along the length, 89 small sections of length 7 m each can fit in a 601 m length large section. The actual cutting length was estimated after subtracting the cutting length per large section.

Table 2.6: Data inputs in the Transportation stage

Transportation to Old Dhaka			
Item	Amount	Unit	Sources /Comments
Diesel (trucks)	4.99	kg/ton	150 L/ 25 ton of load
Transportation to Rerolling mills			
Diesel (trucks)	3.33	kg/ton	100L/25 tons of load

2.2.3.1.6 Light engineering in Old Dhaka city

Steel sections are processed by applying light engineering tools, such as lathe machines. Electricity is used for operating lathe machine whereas gas torches are used for cutting (Table 2.7). A variety of household products are made. I assumed that the electricity cost is 8 taka (10 U.S. cents) per one kwh of electricity.[4] I based our data on an interview with one cutter man. He said, "I can cut 300 meters of half inch metal plate using one LP cylinder [12.5 kg] and five oxygen cylinders [about 12 kg each]."

Table 2.7: Data inputs in Light engineering in Old Dhaka:

6. Light Engineering at Old Dhaka			
Item	Amount	Unit	Sources/Comments
Electricity	157.1	kwh/ton	800 kg iron needs 40 hours; 25-40 kwh per 10-10 hours, source: Interview

[4] https://www.desco.org.bd/?page=tariff-rate (Accessed on 08/15/2015)

Oxygen	9.8	kg/ ton of steel scraps	300 meter of 12mm thick can take 12.5 kg of LP and 62.5 kg of Oxygen, Source: interview. Assumed cutting length per ton = .5625 km-mm/ton.
LP	2.0	kg/ ton of steel scraps	

Figure 2.3: Old Dhaka steel plate processing by cutter men, using gas torches powered by cylindered gases (Photo Credit; First Author).

2.2.3.1.7 Rerolling Mill

To produce rebar, scraps are placed into a furnace fueled by natural gas. The scraps are melted and sent through several molding stages, each of which contributes to reducing the rebar to its required shape and size. The steel is allowed to cool once it is shaped to the required specifications. In a rerolling mill, I asked the working technician for an estimate of the daily output of rods and the mill manager for an estimated monthly electricity bill – thus connecting the energy required for the metal outputs. Recycling efficiency in rerolling mills is 95%, with only 5% loss by weight. Gas consumptions is about 30 m^3 per ton of products based on average of a semiautomatic type rerolling mills (Plembina Institute, 2002). Total output of rebar per month is 1200 tons (Table 2.8).

Table 2.8: Data input in rerolling stage

7. Rerolling stage		
Item	Amount (/ton of steel)	Sources/Comments
Electricity	83.3 kwh	800000 is electricity bill; 8 taka (10 cents) per unit cost. Production 1200 ton per month
Natural Gas	30 m^3	Source: (Plembina Institute , 2002)

2.2.3.2. Primary Rebar Data Collection Inventory

Table 2.9 shows the inputs and outputs of the primary steel production. These data were adapted from Yellishetty et al. (2011). I used data from the hot rolling process that makes rebar. The hot rolling stage assumes a 4 percent loss of inputs (World Steel, 2014). Slag of about 20 percent of the original steel making process is an important byproduct of the cement industry. Environmental impacts were allocated between steel and slags on the basis of mass (Yellishetty et al. 2011).

Table 2.9: Inputs required to produce one ton of liquid steel from virgin iron; adapted from Yellishetty et al. (2011).

Inputs				**Outputs**			
Raw materials	**Units**	**Amount**	**Average**	**Products**	Units	Amount	Average
Iron ore		0.02–19.4	9.71	Liquid steel	kg	1000	
Pig iron	kg/t LS	788–931	859.5	*Emissions*			
Scrap	kg/t LS	101–297	229	CO2	kg/t LS	22.6–174	98.3
Coke	kg/t LS	0–0.36	0.18	CO	kg/t LS	393–7200	3796.5
Lime	kg/t LS	30–67	48.5	NOx	g/t LS	8.2–55	31.6
Dolomite	kg/t LS	0–28.4	14.2	Dust	g/t LS	10–143	76.5
Alloys	kg/t LS	1.3–33	17.15	Cr	g/t LS	0.01–0.08	0.045
Total	**kg/t LS**		**1178.24**	Fe	g/t LS	45.15	45.15
Energy				Pb	g/t LS	0.17–0.98	0.575

Electricity	MJ/t LS	35–216	125.5	SOx	g/t LS	Nil	
Natural gas	MJ/t LS	44–730	387	PAH	mg/t LS	10	10
Coke oven gas	MJ/t LS	0–58	29	*Energy*			
Steam	MJ/t LS	13–150	81.5	BOF gas	MJ/t LS	350–700	525
BF gas	m3/t LS	0.55–5.26	2.905	Steam	MJ/t LS	124–335	229.5
Compressed air	Nm3/t LS	8–26.0	17	*Solid wastes/by-products*			
Gases Oxygen	m3/t LS	49.5–54.5	52	All types of slag	kg/t LS	101–206	153.5
Nitrogen	m3/t LS	0.55–1.1	0.825				
Argon	m3/t LS	2.3–18.2	10.25				
Water	m3/t LS	0.8–41.7	21.25				
• Liquid steel							

2.2.4 Impact assessment methods

I used two methods to estimate the environmental impact of outputs: IPCC 2013 100a and IMPACT 2002+ (Hischier et al. 2010). GWP was evaluated by the IPCC 2013 100a method (a method within the SimaPro modelling software) and calculated by comparing the amount of heat trapped by a certain mass of a specific greenhouse gas in question to the amount of heat trapped by an equivalent amount of carbon dioxide (CO_{2eq}) over 100 years timeframe (IPCC 2013).

IMPACT 2002+ is relatively more comprehensive, built on the Eco-indicator 99 method (Goedkoop et al. 1998). This index quantifies the damage to four categories (general human health, ecosystem services, climate change and resources) through the quantified representation of fourteen midpoint categories. These categories are: human toxicity, respiratory effects, ionizing radiation, ozone layer depletion, photochemical oxidation, aquatic ecotoxicity, terrestrial ecotoxicity, aquatic acidification, aquatic eutrophication, terrestrial acidification/nutrification, aquatic acidification, aquatic eutrophication, land occupation, global warming, non-renewable energy, and mineral extraction (Jolliet et al. 2003). Resources use category in IMPACT 2002+ were used to measure nonrenewable primary energy consumption in MJ within the system boundary. Nonrenewable energy consumption occurs when fossil fuels are used in the production of materials or in the process of mineral extraction (Jolliet et al. 2003). In IMPACT 2002+, human toxicity is calculated based on the Human Toxicity Potentials (HTP) at mid-point and Human Damage Factors (HDF) at end point. HTP is determined by the transportation of chemicals to the environment, human exposure, and the intake fraction resulting either from ingestion or inhalation, combined with an effect factor that estimates the damage on human health. Aquatic and terrestrial ecotoxicity are calculated using the same fate and effect model as used for human toxicity.

A damage analysis correlates mid-point impact categories to damage categories: damage to human health, ecosystem health, climate change and resources (Goedkoop et al. 1998). To assign specific values for human health damage, Disability

Adjusted Life Years (DALY) represents the reduction of life expectancy (or the number of days one is hospitalized in a given year). The Ecosystem Quality (EQ) is expressed as a percentage of species that are threatened or extirpated from a given area and represents values of ecotoxicity, acidification/eutrophication and land use change (Hischier et al. 2010). This is calculated by multiplying Potential Disappeared Fractions (PDF) with the area covered by such emissions times the number of impact years. PDF is used as an end point by converting Potentially Affected Factors (PAF), calculated based on the concentration of toxic substances; the higher the concentration, the larger the number of species that are affected. The resource depletion is expressed in "MJ primary" to represent how the present use of resources leads to the use of an additional unit of nonrenewable primary energy to extract same amount of resources in the future.

Ecotoxicity was calculated using a damage function measured by concentration of toxic substances and percentage of the potentially affected fractions (PAF) of lower organisms such as worms, algae, etc. The calculation of acidification uses a function that connects Probability Of Occurrence of a species (or POO) with the deposition of ammonia, sulphates and nitrates. Land use changes were considered by the combination of the restoration time (if the land was transformed) plus the species lost from the occupation of land. Radiation impact was calculated by the radiation that comes from the exposure of radioactive materials (Goedkoop et al. 1998).

2.3 Results

2.3.1 GWP and Resource use values of secondary and primary rebar production

GWP values for the primary rebar production were larger compared to secondary (recycled) rebar production. Primary rebar production emitted 2250 kg CO_{2eq} whereas the secondary rebar production emitted only 295 kg CO_{2eq}/ ton of rebar (Table 2.10). Likewise, resource consumption was larger in primary rebar production than secondary rebar production. In primary rebar production, resource use was 21252 MJ primary whereas in secondary rebar production, energy use was only 4760 MJ primary, about one fourth of the total energy consumption.

Table 2.10. GWP values for the primary and secondary rebar production

Type of source	Global Warming Potential(kg CO_{2eq})	Resources (MJ primary)
Secondary rebar production	295	4760
Primary rebar production	2250	21252

2.3.1.1 Individual contribution to GWP in secondary rebar production

Secondary rebar production comprises six stages, out of which the rerolling stage contributed 60 % of total GHG emissions. The rerolling stage emitted 183 kg CO_{2eq}, shared by two important processes: about 83.8 kg CO_{2eq} from electricity production in Bangladesh; and 97 kg CO_{2eq} accounts for the natural gas usage, 71.9 of which was due to combustion of the natural gas. In-yard processing emitted about 43.8 kg CO_{2eq} – about one sixth of what was emitted in the rerolling stage. The main contributors in this stage were the combustion of fossil fuels (20.9) and production of liquid oxygen (18.6). Beached ship cutting contributed only 18.4 kg CO_{2eq}, about half of what was emitted in in-yard processing (Table 2.11).

Table 2.11: Stage-wise GWP results for secondary rebar production

Secondary Rebar Production (GWP)		
Stage		**Impact kg $CO_{2\ eq}$ /ton of rebar**
1. Ship transportation before beaching		**30.6**
	Heavy Fuel Oil combustion	26.2
	Heavy Fuel Oil production	4.35
2. Beached ship cutting		**18.4**
	Liquid Oxygen production	16.3
	Fossil fuel combustion	1.91
3. Dragging by winch		**6.16**
	Fossil fuel combustion	5.19
	Diesel	0.97
4. In- yard processing		**43.8**
	Fossil Fuel combustion	20.9
	Oxygen liquid	18.6
5.2. Transportation to Rerolling mills		**13.3**
	Fossil Fuel combustion	11.2
	Diesel	2.1
6. Rerolling stage		**183**
	Electricity	83.8
	Fossil Fuel combustion	71.9
	Natural gas liquefied	25.1
Total		**295**

2.3.1.2 Individual contribution to GWP to the primary rebar production

Primary rebar comprises two stages in our system description – steel making and hot rolling. The steel making unit in primary rebar production emitted more greenhouse gases compared to hot rolling units. Steel making accounted for 1930 kg CO_{2eq}, about six times larger than the emissions from hot rolling operations. The processes with the highest contributions to GWP values were pig iron production, water use and iron scrap. Pig iron production contributed 1710 kg CO_{2eq}, about ninety percent of the total emissions from the steel making operations. This is due to the considerations of the impacts of mining and further processing of iron ore into pig iron. In the hot rolling stage, unalloyed steel contributed most of the emissions – 122 kg CO_{2eq} followed by the heat produced from natural gas (56.7 kg CO_{2eq}) (Table 2.12).

Table 2.12: Stage-wise Global warming potentials results for primary rebar

Primary Rebar Production (GWP)		
Item		**Impact kg CO_{2eq} /ton of rebar**
1. Steel making		**1930**
	Pig Iron production	1710
	Water use	27.5
	Iron Scrap	26
	Electricity	22.6
	Oxygen liquid	20.3
	Ferro manganese	19.9
2. Hot rolling		**318**
	Steel unalloyed	122
	Heat from Natural gas	56.7
Total		**2248**

2.3.1.3 Individual contribution to resource consumption to secondary rebar production

In secondary rebar production, out of 4760 MJ primary, the rerolling stage consumed 3120 MJ. Of that, electricity production and marketing contributed 1550 MJ and LPG contributed 1440 MJ. In-yard processing and beached ship cutting contributed 640 and 242 MJ of energy consumption, shared mostly by the oxygen and LPG use in the gas cutting process. Ship transportation before beaching also contributed to a large portion (465 MJ) of the energy consumption (Table 2.13).

Table 2.13: Stage-wise energy consumption results for secondary rebar

Secondary Rebar Production (Resources)		
Item		**Impact MJ primary/ton of rebar**
1. Ship transportation before beaching		**465**
	Heavy Fuel Oil	465
2. Beached ship cutting		**242**
	Liquid Oxygen Preparation	209
	LPG	33.4
3. Dragging by winch		**93.3**
	Diesel	92.7
4. In- yard processing		**640**
	Diesel	205
	Oxygen liquid	262
	LPG	172
5.2. Transportation to Rerolling mills		**202**
	Diesel	202
6. Rerolling stage		**3120**
	Electricity	1550
	Natural gas liquefied	1440
	TOTAL	**4760**

2.3.1.4 Individual contribution to resource consumption of primary rebar production

The biggest resource-consuming unit operation was steel making, for which pig iron required the most energy (15400 MJ).This was about 90 percent of the total energy consumption, followed by water use, iron scrap, electricity, oxygen liquid and natural gas (Table 2.14). All of those other processes cumulatively used 1600 MJ of resources. The hot rolling unit consumed 4170 MJ of energy, about one third of what was consumed in steel making. The steel unalloyed process consumed 1130 MJ, followed by natural gas heating which consumed 1030 MJ.

Table 2.14: Stage-wise energy consumption for Primary rebar

Primary Rebar Production (Resource use)		
Item		**Impact /ton of rebar**
1. Steel making		**17000**
	Pig Iron production	15400
	Water use	377
	Iron Scrap	359
	Electricity	326
	Oxygen liquid	286
	Natural gas	379
	Ferro manganese	270
2. Hot rolling		**4170**
	Steel alloyed	1130
	Heat from Natural gas	1030
	Electricity	931
	Lubricating oil	386
	Total	21270

2.3.2 Human health and ecosystem quality using IMPACT 2002+ method

IMPACT 2002+ provided four end point damage categories: human health, ecosystem quality, resources and climate change. Here, I present results for two end point damage categories: human health and ecosystem quality. Resource use has been discussed in the previous sections. Consistent with the previous results in GWP and resource consumption, primary rebar resulted in more damage to human health and ecosystem quality.

2.3.2.1 Comparison of human health and ecosystem quality damage of primary and secondary rebar production

The impact on human health during primary rebar production was ten times higher than the impact during secondary rebar production. Human health impact in primary rebar production was 0.0025 DALY and for secondary rebar production, it was 0.000186 DALY. Similarly, ecosystem quality damage in primary rebar production was about six times higher. Ecosystem quality damage in primary rebar production was 305.98 PDF*m^2yr whereas that in secondary rebar production was 52.4 PDF*m^2yr (Table 2.15).

Table 2.15: Damage comparison between primary rebar production and secondary rebar production using IMPACT 2002+

Damage category	Unit	Primary rebar production	Secondary rebar production
Human Health	DALY	0.0025	0.000186
Ecosystem Quality	PDF*m2*yr	305.98	52.4

2.3.2.2 Stage-wise human health results for secondary rebar

I found that the rerolling stage contributed most of the damage to human health from the secondary rebar production. Out of total 0.000186 DALY, rerolling comprised about 63 percent of total human health impact, followed by the in-yard processing stage which represented 26 percent of the damage to human health. In the rerolling unit, liquefied natural gas (to power the furnace) constituted 40 percent of damage to the total human health whereas electricity use contributed only 26 percent. In-yard processing's most damaging activity was ship cutting, and cutting emissions represented 13 percent of the total human health damage. Ship cutting emissions included heavy metals to the air which cause respiratory problems. Beached ship cutting represented the third most impactful stage with 6.75 percent damage to the total human health (Table 2.16).

Table 2.16: Stage-wise human health results for secondary rebar

Secondary Rebar Production (Human health)			
Item		**Impact DALY/ton of rebar**	**% of Total**
1. Ship transportation before beaching		**0.0000035**	**2.06**
	Heavy Fuel Oil production	0.0000035	
2. Beached ship cutting		**0.0000115**	**6.75**
	Liquid Oxygen	0.000004	
	Ship cutting emission	0.00000763	4.47
3. Dragging by winch		**0.000000755**	**0.44**
	Diesel	0.000000755	
4. In-yard processing		**0.000045**	**26.4**
	Diesel	0.00000166	
	Oxygen liquid	0.0000199	11.7
	Ship cutting emission	0.0000219	12.8
5.2. Transportation to Rerolling mills		**0.0000016**	**0.95**
	Diesel	0.0000016	
6. Rerolling stage		**0.000103**	**63**
	Electricity	0.0000339	
	Natural gas liquefied	0.0000687	40
Total		**0.000186**	**100**

2.3.2.3 Stage-wise Human health results for Primary rebar

In this category, the steel making stage comprised 85.3 percent of the damage to human health compared to the hot rolling stage which represented only 13.4 percent of the damage. Among the processes that constitute the steel making stage, pig iron production represented 75 percent of total human health damage (Table 2.17).

Table 2.17: Human health impact results of primary rebar production:

Primary Rebar Production (human health)			
Item		**Impact /ton of rebar**	**% of Total**
1. Steel making		**0.00213**	**85.3**

	Pig Iron production	0.00188	75.6
	Water use	0.0000299	1.2
	Iron Scrap	0.0000342	1.3
	Ferro manganese	0.000126	5.04
2. Hot rolling		**0.000335**	**13.4**
	Steel unalloyed	0.000131	5.27
Total		**0.0025**	**100**

2.3.2.4 Stage wise ecosystem quality damage for secondary rebar

Unlike the previous categories of secondary rebar production, the rerolling stage was not a major contributor to environmental degradation. In-yard processing was responsible for the most damage on ecosystems, accounting for 64 percent. Specifically, ship cutting emissions represented 59 percent of the damage, followed by the liquefied oxygen process that contributed only 3.8 percent. The beached ship cutting stage contributed 22 percent to the overall ecosystem damage. Of that, ship cutting emissions shared 20.6 percent. The rerolling stage represented only 11.8 percent of the damage (Table 2.18).

Table 2.18: Ecosystem quality damage resulting from secondary damage production:

Secondary Rebar Production (ecosystem quality)			
Item		**Impact DALY/ton of rebar**	**% of Total**
1. Ship transportation before beaching		**0.666**	**1.3**
	Heavy Fuel Oil	0.666	1.3
2. Beached ship cutting		**11.2**	**22**
	Liquid Oxygen	0.396	0.7
	Ship cutting emissions	10.5	20.6
3. Dragging by winch		**0.137**	**0.26**

	Diesel		
4. In-yard processing		**32.8**	**64.1**
	Diesel	0.3	0.5
	Liquid Oxygen	1.96	3.83
	Ship cutting emissions	30.2	59.2
5.2. Transportation to Rerolling mills		**0.293**	**0.574**
	Diesel	0.293	
6. Rerolling stage		**5.87**	**11.8**
	Electricity	4.17	8.16
	Liquefied natural gas	1.7	3.13
Total		52.4	**100**

2.3.2.5 Stage wise ecosystem quality damage for primary rebar

In this stage, steel making continued to be a dominant source of ecosystem damage, sharing 86.7 percent of total ecosystem damage (Table 2.19). In the steel making stage, pig iron production represented a 76 percent share of damages, while other process had only minor impacts on the environment. The hot rolling stage contributed only 11.3 percent.

Table 2.19: Ecosystem quality damage resulting from Primary rebar production:

Primary Rebar Production (ecosystem quality)			
Item		**Impact,** PDF*m2*yr **/ton of rebar**	**% of Total**
1. Steel making		**268**	**86.7**
	Pig Iron production	233	76
	Water use	9.12	2.98
	Iron Scrap	8.99	2.94
	Electricity	1.97	0.644
	Oxygen liquid	2.14	0.7
	Ferro manganese	8.9	2.91

2. Hot rolling		**34.6**	**11.3**
	Steel alloyed	17.9	5.85
	Heat from Natural gas	1.48	0.485
Total		**305.98**	**100**

2.3.3 Recycling vs light engineering comparison

In the final stage of ship recycling, the processing divides the metal resources into light engineering activities which produce household products, and recycling in rerolling mills which produces rods and rebar. When comparing the light engineering stage in Old Dhaka with the rerolling stage (for an equal product weight of one ton), the rerolling stage dominated in GWP and resources categories while light engineering dominated in ecosystem quality and human health categories. In the rerolling stage, GWP and resource use represented 174 kg CO_{2eq} and 2961.6 MJ primary whereas in light engineering, these categories represented 59.4 kg CO_{2eq} and 955 MJ primary respectively. In both categories, the rerolling stage contributed three times the impacts of the light engineering stage.

However, in the light engineering stage, the human health and ecosystem categories represented a larger share of impacts. Human health impacts during the light engineering stage represented 0.00024 DALY compared to 0.0001 DALY in the rerolling stage. Ecosystem damage represented 275.9 PDF*m^2 *yr compared to 5.7 PDF *m^2 *yr; environmental impacts during the light engineering stage were 50 times higher than in the rerolling stage. This may be due to the much longer cutting lengths of the steel in this stage. Based on the data from the interviews, I estimated that the cutting length is about 33 meter per ton of rebar compared to the smaller sections of the in-yard processing where the cutting length was estimated at about 5 meter per ton. This much longer cutting length emits heavy metals, which contribute to ecosystem damage (Table 2.20).

Table 2.20: IMPACT 2002+ value comparison between rerolling stage and light engineering stage.

Damage assessment between Recycling and Light engineering			
Damage category	**Unit**	**7. Recycling in rerolling mill**	**6. Light engineering in Old Dhaka**
Human health	DALY	0.00010	0.00024
Ecosystem quality	PDF*m2*yr	5.7	275.9
GWP	Kg CO_{2eq}	174	59.4
Resources	MJ primary	2961.6	955.2

2.4 Discussion

2.4.1 Primary rebar vs secondary rebar

Based on these results, I conclude that overall, primary rebar production produces more negative environmental impacts than secondary rebar production. More human health damage occurs in the secondary rebar production, due to torch cutting. Ecosystem quality damage in secondary rebar production was determined mostly by the in-yard processing and also in the processing steps in Old Dhaka. In both systems, there is a re-rolling unit operation where steel is transformed into rebar. The impacts for re-rolling were much higher in the primary rebar production system due to the type of technology used in the unit operation in addition to scale, efficiency and the type of fuel used. The stage that was responsible for the most impact of primary rebar was pig iron production. This stage takes into account all environmental impacts related to iron ore mining and later processes such as iron pelleting and sintering. Old Dhaka processing of secondary production damages ecosystems more than the rerolling mills. Using rebar made from ship recycling scraps thus saved 16492 MJ worth of resources and avoided 1955 kg of CO_2 emissions. Despite the positive contribution to global sustainability, negative local impacts due to ship recycling are still emphasized in scientific and political spheres (Chapter 3; Hossain and Islam 2006). However, our study suggests that the workers' health and ecosystem damage in primary rebar outweighed secondary rebar production by ten and six times respectively (Table 2.15). These impacts were however diffused and spread across the global supply chain, as the iron producing countries are not always producing steel (Worrell et al. 1997)

Our study also provides important insights regarding the most damaging stages of secondary rebar production. This most damaging stage involves the rerolling units, followed by the in-yard ship cutting and beached ship cutting (Figure 2.4). In all categories, the damage generated by rerolling units dominated the other two stages,

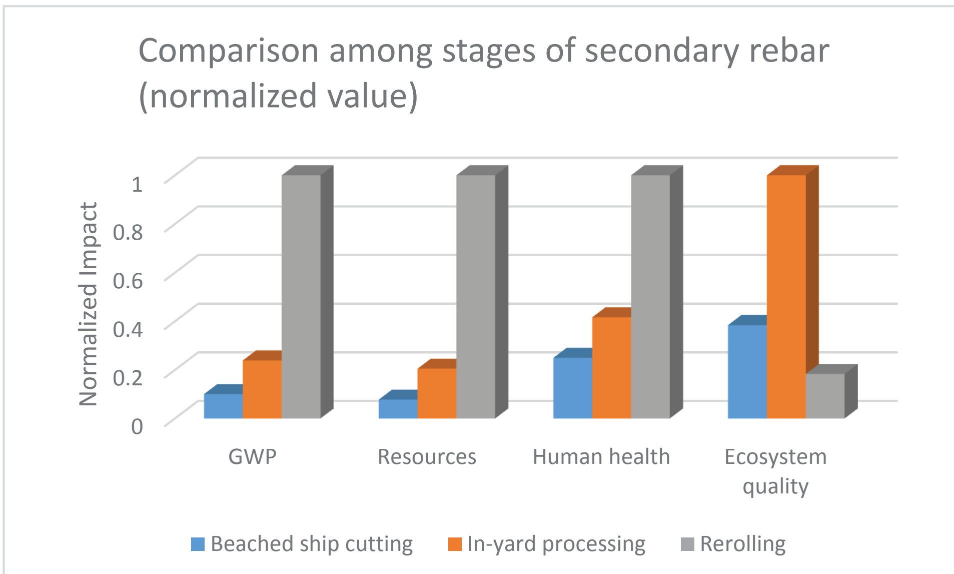

Figure 2.4: Comparison among stages of secondary rebar by normalizing data. Normalization is done by dividing the all category values by the largest value of the categories, making the largest value equal to 1.0.

except in the ecosystem quality category where the maximum damage occurred during in-yard processing, followed by beached ship cutting. This result reflects the possible waste discharge to the surrounding environment in the beached ship cutting and in-yard stages (Table 2.4).

What can explain the higher ecosystem damage for the in-yard processing and beached ship cutting process? In IMPACT 2002+, ecosystem quality is composed of six midpoint categories (Table 2.21). In all impact categories, liquid oxygen use accounted for more than 80 percent of each category, except for terrestrial ecotoxicity, with high emissions (94 %) during ship cutting. Thus, the end point ecosystem damage was a result of the use of liquid oxygen and the use of gas torches while cutting. The use of liquid oxygen and its quantity was confirmed by our respondents. The cutting emissions depend on the cutting length of metals in the yard (as estimated from our interviews).

Table 2.21: Ecosystem damage results by percentage during in-yard processing

Impact category	**Total**	**Liquefied petroleum gas**	**Liquid Oxygen**	**Diesel**	**Beached ship cutting emissions**
Aquatic ecotoxicity	100	5.17	40.06	6.04	48.73
Terrestrial ecotoxicity	100	0.64	4.39	0.74	94.23
Terrestrial acidification/nutrification	100	9.78	79.34	10.41	0.47
Land occupation	100	6.30	86.81	6.90	0.00
Aquatic acidification	100	9.01	81.70	9.13	0.17
Aquatic eutrophication	100	7.64	83.51	8.85	0.00

Ecosystem damage from beached ship cutting was roughly similar to damage from in-yard cutting. Most of the mid-point damage can be attributed to the use of liquid oxygen and the use of gas torches. However, the inclusion of waste discharge to the surrounding environments showed minimal (only 0.3 percent) impact on the ecosystem category (Table 2.22). This result challenges the epistemic community – a knowledgeable group concerned over an issue area – which claims that the damage to local ecosystems is primarily due to the discharge of the ship's waste residues (Gough and Shackley 2001) (Chapter 3).

Table 2.22: Ecosystem damage results in percentage in beached ship cutting.

Impact category	**Total**	**Liquid Oxygen**	**LPG**	**Beache d ship waste**	**Beached ship cutting emissions**	**Fossil fuel combustion**
Aquatic ecotoxicity	100	29.31	8.94	0.31	61.43	0.00
Terrestrial ecotoxicity	100	2.58	2.02	0.00	95.40	0.00
Terrestrial acidification /nutrification	100	89.27	9.81	0.00	0.92	0.00
Land occupation	100	29.43	70.5 7	0.00	0.00	0.00
Aquatic acidification	100	96.40	3.26	0.00	0.34	0.00
Aquatic eutrophication	100	91.64	8.36	0.00	0.00	0.00

Human health impacts from the beached ship cutting and in-yard ship cutting were also due to the use of gas torches that cause respiratory disorders. Table 2.23 shows that 63 percent of carcinogens were caused by using gas torches for cutting and 33 percent by using liquid oxygen. 87 percent of non-carcinogens were attributed to torch cutting and 12 percent to the use of liquid oxygen. Cutting activities were the source of 98 percent of respiratory organics and 61 percent of respiratory inorganics. Similarly, in in-yard processing, torch cutting dominated the ecosystem damage contribution (Table 2.23). The cutting emissions released heavy metals such as cadmium, iron, lead, particulates, and others into the air during combustion (Sobaszeket al. 2000). This result is important to policy makers, as the greatest impact on workers' health was caused by the use of gas torches during cutting. Thus, the respiratory disorder of the cutters were most likely persistent in all subsequent stages (e.g. Bhatiary and Old Dhaka processing) across the country that involve cutting, unless the remedial policies consider the impacts of all stages (Table 2.23).

Table 2.23: Results in percentage of mid-point categories in beached ship cutting and in-yard processing.

Stage	**Process**	**Carcinogens (100%)**	**Non carcinogens (100%)**	**Respiratory organics (100%)**	**Respiratory inorganics (100%)**
Beached ship cutting	Torch Cutting	63	87	98	61
	Liquid oxygen	33	12	0.4	36
	Ship waste	0	0	0	0
In-yard processing	Torch Cutting	47	79	96	45
	Liquid oxygen	42	18	0.7	46

2.5 Study Limitations

Many of the limitations of our analysis stem from the lack of available local data. Since this study used the Ecoinvent database, primarily built on European data and contexts, the perceived damage to human health and ecosystems will be different in Bangladesh. In IMPACT 2002+, I have used a hierarchical approach that considered only scientifically proven causality, but human susceptibility varies widely from the developed countries to developing countries as the people in developing countries seem to be resistant and thus, indifferent, to various risky practices.

In this study, I could not incorporate accidents or injuries, which would have impacted the index of human health significantly. For example, the following Table 2.24 reflects the number of deaths on highways and in the garments industries. Although there are no annual data of number of deaths in the shipbreaking yards, most studies claim that the number of deaths ranges from 279 -400 from its inception about 20 years ago (Sujauddin et al. 2014). This comparison shows that the number of deaths in the yards is much less as compared to the other sources of mortality in the country.

Table 2.24: Comparison of deaths and injuries of shipbreaking with other industries (http://www.police.gov.bd/Crime-Statistics-comparative.php?id=208, accessed on 02/12/2015).

Name	2008	2009	2010	2011	2012	2013
Deaths in Ship breaking	16	13		10	11	20
Road accident	4427	3381	2827	2667	2636	2029
Number of Deaths in road accident	3765	2958	2646	2546	2538	1957
Murder cases	4099	4219	3988	3966	4114	4393
Death in Garments	87 (2005)	96 (2006)	47	2	124	1168

In addition, this study was not able to estimate the benefits derived from the ship recycling industry such as employment generation, or provision of important resources to the construction sector (Chapter 1).

I used data from interview respondents which was most often experiential and not formally measured. Thus, these data were subjective. However, I attempted to verify these data with other sources to boost precision and accuracy. This study was also limited by the inability to incorporate social dimensions of damage, which would consider workers' wages, occupational health hazards, injury rate, exposure to toxic chemicals and training facilities. However, the importance of further study is also indicated by the high ecological damage potential.

2.6 Recommendations and Conclusions

I focused on the stages of the ship dismantling process in Bangladesh, starting from the transportation of retired ships from the originating country to the domestic processing via on-beach dismantling. This study is the first to formally apply a Life Cycle Assessment to ship dismantling in its entirety in this country. This study can be applied to ship dismantling operations in other developing countries such as India and Pakistan, as they use similar technology and human energy to produce scraps.

Our findings suggest that a clear environmental benefit exists in recycling steel from ship scraps, relative to the use of steel from virgin ore. We also found that the rerolling stage should be the priority for additional attention to reduce its environmental impacts, through energy efficient technologies that reduce the consumption of electricity and natural gas. However, the impacts generated by this stage are mostly global, spread along the global supply chain for the production of electricity and natural gas. Much less local impact occurred in this stage.

Both in-yard processing and beached ship cutting stages generate less impact via waste discharge to the soil, water and environment than the stages beyond the yard activities. High localized impacts were estimated in torch cutting, which should be addressed in both beached ship cutting and in-yard processing stages. Thus, our policy recommendations would involve more concentration on how to reduce the impacts on cuttermen's health while cutting. Protective gear, training, and/or sophisticated technology would improve the situation.

It is important to note here that the lead author observed that the use of gas torches was not limited to only the ship recycling yards. Torches are used in the secondary processing zone across the country, with significant use in Bhatiary, Chittagong and Dholaikhal, Postogola in Old Dhaka city. Those regions are noted for their contribution to the national economy. As such, the national government should provide them necessary support through the introduction of technologies that would better protect their health and improve their working environment.

Finally, this study does not suggest that this industry is non-polluting. Rather, it suggests that epistemic community including natural scientists has so far misprioritized their attention, focusing on wastes discharged to the coastal water. Improvements in other areas, such as the technical side of rerolling and in gas torches for cutting, is expected to result in more significant improvements in environmental and working conditions. For secondary rebar production, our results run contrary to the widely held perception that ship recycling pollutes the surrounding environment extensively. However, our study suggests that the rerolling activities that happen outside of the yards are responsible for the most damage, particularly for waste discharged into the environment. Adverse impact due to in-yard processing and beached ship cutting is generated by the use of liquid oxygen and the use of gas torches – with global impacts. Changes in cutting methods or use of protective gear during cutting will largely reduce the local environmental and health impacts.

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Chapter 3: Breaking ships to build a nation: The Political Ecology and Scalar Politics of the Bangladeshi Shipbreaking Industry[5]

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Abstract

Shipbreaking in the Chittagong region of Bangladesh supplies scraps to meet the needs of the nation's construction sector. The shipbreaking industry has received international attention as an environmentally damaging industry that is dangerous for its workers. Here we examine this prevailing image of shipbreaking using a political ecology framework, particularly related to the politics of scale, to illuminate how the perspectives and motivations of different actors contribute to this image. Although shipbreaking practices in Bangladesh have improved significantly to reduce environmental contamination and worker accidents, the prevailing negative image has not changed. National and international NGOs enforce a discourse focused on local negative impacts while failing to acknowledge improvements, as a consequence shifting attention away from the inadequate enforcement of international treaties. This NGO perspective may also influence research on the industry, leading to

[5] A modified version of this chapter will be submitted to *Journal of Political Ecology*

methodological flaws (such as ignoring safety improvements in the breaking yards and effluents from other nearby industries). This skewed discourse continues to obscure the identification of viable solutions to existing environmental and social problems, and hence drives ineffective policy implementation.

Key words: Political ecology, Scale, Shipbreaking, NGOs, Environmental contamination, working conditions.

3.1 Introduction

The conditions are harsh, no doubt, on the shore of the Bay of Bengal, where thousands of barefoot Bangladeshi citizens dismantle ships that are at the end of their seafaring life. These ships arrive at the Bay of Bengal and are scrapped right on the coast to be repurposed for scrap metal. The metal is used for construction and development and sold for cash to external markets. The storyline seems relatively straightforward: billion-dollar shipbreaking companies find ports of an economically marginalized country with little to no environmental regulations to deal with the waste of vessels, which bring with them tremendous amounts of pollutants. During the course of this development, mangrove forests along the delta, which are critical habitats for the fisheries that have historically supported Bangladeshi families, have been decimated. Thus, a cycle of reliance on international markets and perpetual environmental degradation continues. In this paper, we unpack this narrative, analyze the framing of the "blame," and offer suggestions for better safeguarding the workers and the ecological systems that are the most impacted by (and least protected by) the conditions. We do this using a political ecology perspective to analyze the discourse of multiple actors involved in the shipbreaking industry, including workers, managers, owners, NGO representatives and government officials.

Political ecology highlights the relationship between political economy and environmental systems, with particular attention focused on the social power settings that influence these interactions (Blaikie and Brookfield 1987, Bryant 1992, Bryant 1997, Bryant 1998, Paulson et al. 2003). Human–environment interactions can be influenced by unequal power arrangements in a particular society; these arrangements construct social reality and often have linkages to global and national level issues (Bryant 1998). Central to political ecology discourse is the identification of actors at various levels to explore hidden relationships that impact the access and use of resources (Blaikie and Brookfield 1987, Bryant 1992, Bryant 1997, Bryant 1998, Mehta 2007, Rasul 2007, Robbins 2011).

Using a political ecology frame, this paper examines the shipbreaking industry in Bangladesh and how actors at various scales, particularly international and national NGOs versus local stakeholders, frame this industry's activities. Globally connected domestic firms in developing countries are embedded in a complex system of socioecological relationships where power, interests, and contexts interact through the mobilization of discourses and perspectives (Blaikie and Brookfield 1987, Hecht and Cockburn 1989, Peluso 1994, Bryant 1998, Girdner and Smith 2002, Swyngedouw and Heynen 2003, Escobar 2011). While the global discourse often consists of "shared myths and blueprints of the world," such discourse is often inappropriate to the local reality (Adger et al. 2001, Ahmed 2001, Paulson et al. 2003, Bulkeley 2005, Norman and Bakker 2009).

There are three ways that a dominant discourse can bias academic research on the human-environment nexus (Bryant 1997). First, the assumption that poverty pollutes the environment is prevalent. The primary reason for environmental problems is the assumed overdependence of poor people on the environment (Broad 1994). Second, this assumption limits inquiry into other possible culprits, such as foreign investment, trade, or environmental politics, particularly those that originate at broader scales (Cole 2004, Rasul 2007, Meyfroidt et al. 2013, Antoci et al. 2014, Munroe et al. 2014). Third, the assumption that the dominant global perspective is the closest to the truth leads to its uncritical acceptance without acknowledgement or understanding of the complexity of the issue, due to scalar politics (Bryant 1997, Smith and Pangsapa 2008, Princen et al. 1994). A more complete understanding of the complex connection between poverty and the environment can be gained by increasing the direct participation of the poor in environmental research (Beierle and Konisky 2000, Shepard 2002). However, despite these efforts, the full resolution of many local issues often lies in economic and political forces operating at an international scale, involving local impacts that are largely out of local control (Bryant 1992, Bryant 1997, Girdner and Smith 2002, Cole 2004, Rasul 2007).

Peet et al. (2010) recommends reassessing the knowledge produced by the epistemic community by providing alternative explanations of social and environmental problems that seek to challenge dominant perspectives (Sardar 1999; Peet et al. 2010). Outsiders often view populations in economically marginalized communities and countries as “others” who lack the ability or incentive to properly resolve their own problems (Adger et al. 2001; Escobar 2011; Robbins 2011); researchers hailing from these countries are not immune from the influences of the dominant discourse (Said 1979; Mitchell 1991). They too may frame their work as studying “others” who need to be described and developed (Escobar 1996, Escobar 2011). This creates the dependence of a society that is stunted in their capacity to articulate their own identities and worldviews. Some cultures and societies, as a result, can find themselves reliant upon dominant representations and surrendered to imposed meanings, ambitions and projects (Munck and O'Hearn 1999).

The politics of scale literature explores how scale is constructed and mobilized (Brown and Purcell 2005; Bulkeley 2005; Neumann 2009; Norman et al. 2012). Often, a dominant discourse is created by a group of people in a privileged position and reified through policies, laws, and sets of principles. Through their expanding networks with international actors, local NGOs enjoy ever increasing capacity to popularize a certain discourse, underscoring the need to understand issues through the scale politics (Brosius and Tsing 1998; Murdoch and Abrams 1998 Agarwal and Gibson 1999; Brosius et al. 2005; Ribot et al. 2006, Norman et al. 2012). In this case of NGOs controlling scale politics and discourse, the local conditions (e.g., poor health and a degraded natural environment) draw attention away from drivers at larger scales, facilitated through local NGOs access to international media outlet (Cox 1998; Macleod 1999). Drawing perceptions from across stakeholder groups reveal the hidden biases arisen from scale politics by local NGOs.

We use a discourse framework analysis (as described in Adger et al. 2011) to evaluate the role of different perspectives on the environmental and social impacts of the shipbreaking industry in Bangladesh. First, we identify expressions of discourses, then we analyze the actors producing, reproducing and transforming these discourses, and finally we examine the social and policy outcomes of this discourse. Following the suggestions of Munck and O’Hearn (1999), we focus on the first order constructs of the people at the heart of the environmental problem, compared with the second order constructs of the researchers (Munck and O'Hearn 1999, Smith and Pangsapa 2008).

3.2 Study area and Methodology

The Bangladesh shipbreaking yards provide a significant source of metal and steel to meet local demand due to the absence of virgin iron ore in the country. More than 70 percent of domestic steel demand is met by the resources coming from the breakdown of ships in the shipbreaking yards along the coast (Sarraf 2010). The yards also provide employment for more than 50,000 people directly, and more than 100,000 people are indirectly employed (Hossain and Islam 2006, Sarraf 2010). This industry recycles and reuses metal scraps that contribute to the reduction of global environmental impacts by reducing the need for the mining of virgin iron ores (Chapter 2). The shipbreaking yards are situated in Sitakunda Thana, Chittagong. There are about 100 yards operating along the coastal areas in Sitakunda, mainly in Kumira, Bhatiary and Fouzdarhat. The yards occupy only about 4,000 m^2 of land, representing intense economic activity per square meter of land (Rahman and Mayer *in press*).

Figure 3.1 shows a typical yard where ships are broken into pieces and the metal is transported to the market for sale. The ship that is half dismantled and the one that has just a small remaining internal structure at the far right side of the figure belong to different yards; this illustrates the small size of each yard. The ships are first dismantled into bigger sections, and then those bigger sections are dragged by the winch during high tide to the end of the muddy areas beyond the water line. Cuttermen

Figure 3.1. Shipbreaking yard, Chittagong, Bangladesh

use blowtorches to cut these large sections into smaller sections, which are then carried by the magnetic grabs (in the foreground) to the trucks. Any small, lightweight pieces are carried by the workers from the ships into the dry areas and organized into categories to be sold. A massive scale (lower right) weighs both unloaded and loaded trucks to measure the amount of metals sold. All of this equipment greatly reduces the amount and weight of metal that workers must carry from the ships to the yards.

3.3 Field Work: Interviews

To capture multiple perspectives and narratives of the shipbreaking industry, the lead author – who is originally from Bangladesh and speaks fluent Bengali – spent two field seasons studying the shipbreaking industry at the yards and in the nation's capital, Dhaka. From May through August 2014, and December 2014 through March 2015, the researcher observed the entire process of the shipbreaking industry, took ethnographic notes, and conducted formal and informal interviews in Bengali – translated later into English - with a diverse range of actors involved in the industry. Data collection followed Michigan Technological University's Institutional Review Board (IRB) protocols for ethical standards, and IRB approval was secured prior to initiating data collection, including a dissemination plan of results. The lead author's position as a Bangladeshi citizen and a U.S. doctoral student may have helped secure access to otherwise inaccessible sites and offered a unique opportunity to gain the perspectives of the laborers working in the yards.

The lead author interviewed a diverse range of actors, including: yard owners and managers, yard workers (e.g., security guards, cutter men, loaders, foremen), metal recycling businessmen, NGO officials, researchers, academics, government officials, and locals (e.g., mosque leaders, fishermen). Several key interviews included: a yard owner, an official from the Department of Environment (a government organization which used to supervise the shipbreaking yard), several top officials of the Ministry of Industry, which is now responsible for addressing shipbreaking issues, and workers (including cutterman). Officials from each of two non-government environmental organizations were interviewed: the Youth Power in Social Action (YPSA) located in Chittagong, Bangladesh; and the Bangladesh Environmental Lawyers Association (BELA) located in the capital city, Dhaka. This research project involved a total of 39 interviews.

Employing both open and closed ended questions, interview questions were tailored to the type of interviewee such that the questions would be relevant and not place the interviewee in an uncomfortable position, potentially leading to false information. For example, when a yard manager or security personnel was interviewed, questions were asked that would not illicit information, seemingly unknown to them (such as funding sources of NGOs). The venue of the interviews ranged from working in the yard, offices, and at home.

Gaining access to the yards was not easy. Initially, yard activities were observed from outside the gate, as entry of outsiders to the yards is restricted. However, access to the yards was granted gradually; ultimately four yards were

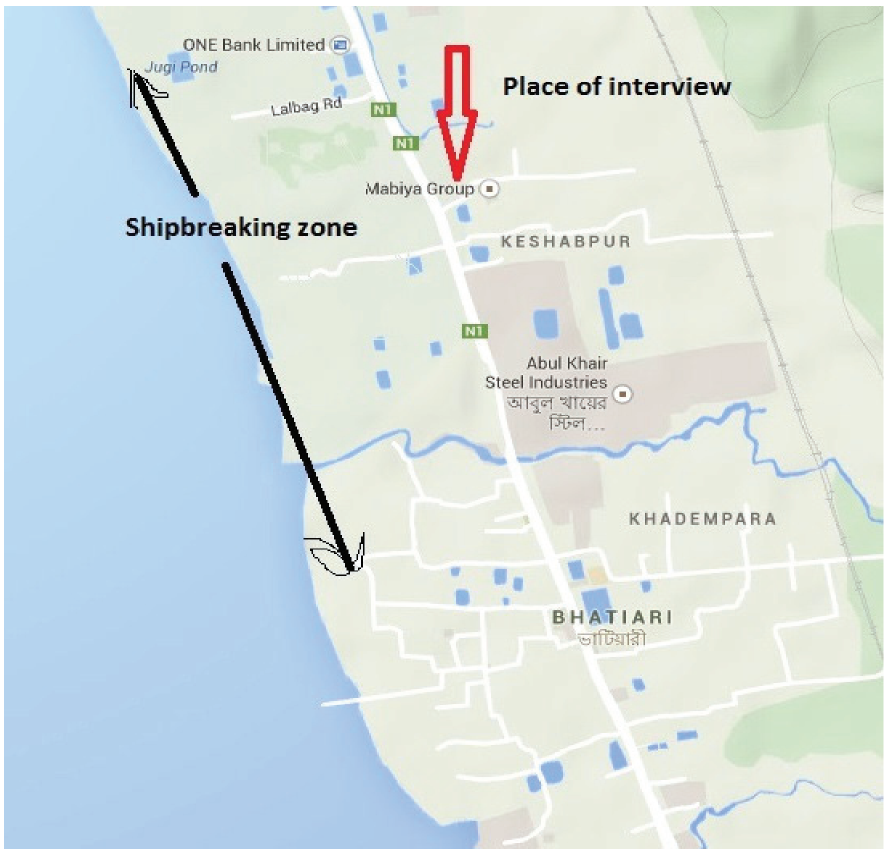

Figure 3.2 Mabiya Shipbreaking yard, Chittagong, Dhaka

observed from the inside, while nine others were viewed from the outside (Figure 3.2). During one visit, the lead researcher stayed in one of the main shipyards for three days and two nights, talking with 25 people from all levels of employees including workers (9-10), a foreman (1), a cook (1), security personnel (3), and local traders.

3.4 Results and Discussion

The interviews reveal a diverse range of perspectives around environmental and health impacts of the shipbreaking industry (Table 3.1). Interviewee responses could be broadly divided into two categories. One group (officials of the Department of Environment, Ministry of Industry, yard officials, workers and a few researchers) felt that shipbreaking practices were improving, with some issues that remain to be addressed. Another group (local and national NGOs such as YPSA and BELA) denied any improvement and believed that shipbreaking is becoming more hazardous. These disagreements primarily centered around environmental damage and worker safety, although other issues such as bribery and finances, law enforcement, and growth of the industry were also contentious.

Table 3.1. Actors and perspectives revealed through open-ended interviews in Bangladesh

Actors	No. of interviews	Summary of interviews
Ship-owners	None	
Yard owners/officials	4	Yards have improved and the accidents are insignificant compared to other industries.
Workers	13	Workers are both happy to work and realize the work is risky. They want this industry and do not want it to stop.
GOs (Ministry of Environment,	5	The industry is much improved but needs international investment to enhance capacity building.

Ministry of Industry)		
NGOs (YPSA and BELA)	3	Yards did not improve and continue to pose a danger to workers and the environment
Professors	4	There is a need to assess the sources of contamination; need proper data to explore the issues.
Local People	10	Local people do not blame this industry as they blame the other chemical industries in the area; instead they view this industry as a job opportunity.

3.4.1 Environmental issues

The current dominant discourse by NGOs points to two major environmental impacts along coasts due to the shipbreaking activities: polluted effluents and deforestation of coastal mangroves.

3.4.1.1 Pollution

Most research on shipbreaking conforms to the dominant view that the industry pollutes the environment (Hossain et al. 2008, Siddiquee et al. 2012). Few studies compare the socioeconomic and environmental conditions of Bangladesh and contrast the shipbreaking industry with other domestic industries, with the exception of Buerk (2006) and Cairns (2007), who focus on employment status before the shipbreaking industry expanded. This study aims to fill this lacuna.

Research conducted in collaboration with NGOs on shipbreaking often identifies the source of most contaminants as the ship breaking yard areas. For example, Siddiquee et al. (2012) stated: “any discharge like spillage of oil, lubricant, grease, POPs [Persistent Organic Pollutants], etc. are spilled or thrown into the coast during the shipbreaking operation” (Siddiquee et al. 2012, p. 79; also see Hossain et al. 2008, Siddiquee et al. 2012, Abdullah et al. 2013). This statement that exclusively identifies shipbreaking activities as the source of discharges of contaminants to the water is contradicted by the statement in a later paragraph that states: “Heavy metals [are] introduced into the environment by dumping domestic and municipal wastes, industrial effluents, urban runoff, agricultural runoff, atmospheric depositions and incorporated into the marine sediments” (Siddiquee et al. 2012, p. 79). While the elements in the sediments are said to be sourced from a diversity of establishments, the title of the study, “Heavy Metal Pollution in Sediments at Shipbreaking Area,” suggests that the shipbreaking industry is the primary source of the contamination.

The similarity of pollutants discharged from the shipbreaking yards and those from other nearby industries raises the possibility that coastal pollution could be attributed to multiple industries. For example, heavy metals such as iron, zinc, manganese and copper have been found above the standard level in the effluent of the steel making industry (Beh et al. 2012). Siddiquee et al. (2012) found in the shipbreaking area that heavy metals such as iron, manganese, chromium and copper are above the standard limits as well (Khan and Khan 2003, Siddiquee et al. 2012). This suggests that the same heavy metals found in the steel making industries may also contaminate the coastal waters. Similarly, textile mills and chemical factories discharge effluents filled with high concentrations of heavy metals, and these same waters also run past the yards.

Both the Director of the Environment and a professor at the Institute of Marine Science and Fisheries acknowledged shortcomings in the Siddiquee et al. (2012) study. When asked if the high concentration of the contaminants found in the coastal water can be directly attributed to the yards, the professor said, "I do not know the source, and indeed there is a high chance that the other industries may also be liable, however we did not have those data. There is no study that separates how much of the pollutants are coming from those chemical industries and how much are sourced from the remnants of shipbreaking activities." The director of the Department of Environment in Bangladesh also acknowledged that "finding out about who else is causing the contamination of the pollutants will reduce the negative image of the yard." The DOE official also remarked, "Look at the main rivers of our country. For example consider Burigonga [a river that surrounds the capital city, Dhaka]. Why is the river water highly polluted? No shipbreaking activities are there except the chemical industries, garments industries, and tannery industries. Of course, those industries have high effluent discharges." The professor of the Institute of Marine Science and Fisheries stated that "it would be interesting to know about the possible contribution of contaminants from the other industries. There are reports that they underuse the Effluent Treatment Plant (ETP) in order to save on operating costs."

One local fisherman explained, “The reason for the gradual reduction of our catches could be traced to the factories situated in the higher hilly areas which discharge chemicals, dyes, and other poisonous pollutants into the waterways that even kill snakes in the streams.” Thus, there is the recognition among local stakeholders that this area is comprised of multiple industrial sectors, one or more of which may be responsible for the pollution observed along the coast.

When asked how much of the pollutants the other chemical industries may discharge as compared to shipbreaking, the NGO official said, “The other chemical industries are discharging much less, at levels that may not have an impact.” However, a representative reporter for the YPSA on shipbreaking stated that the area in Sitakunda “is a zone of industrial wastes where all other chemical industries are operating with or without Effluent Treatment Plants (ETP), discharging waste effluent to the coastal water.” A yard manager commenting on the quantity of the discharge of shipbreaking yards per ton estimated one kilogram (kg) per ton of recovered metal, whereas the NGO officials estimate 40 kg per ton. An official from the Department of Environment countered the NGO official’s view by stating, “There is no way that per ton there may be 40 kg of waste. It is unbelievable. No one in our country wants to throw money to the water as those [materials] have market value.” An LCA of the metal recycling systems in Bangladesh also counters this NGO perspective The impact of waste discharged into coastal waters causes ecotoxicity of about 0.3 percent, as compared to cutting emissions, which are responsible for 61 percent of the aquatic ecotoxicity in the region, primarily generated during the early stages of scrap processing and not just in the shipbreaking yards (see Chapter 2).

According to local interviewees, there are multiple local pollution sources other than the shipbreaking yards. A local shopkeeper mentioned, "The textile factory [Sunman textiles] often discharges their wastes either at night or on a weekend during high tide, as the canal is filled up with water during high tide and pollutants become less noticeable when mixed with tidal saline water. This company received about a 9,000 dollar fine by the Department of Environment." When asked about the fine, one DoE officer said that, "Yes, such cases happen, even I have fined many other industries around the area. The total fines this department issued may be around 10-15 crores taka [about 1 million USD]." The Kumira canal is another canal that one local said "was problematic; once or twice in fifteen days the local PHP tin [a local company name] and chemical industries released effluent which turned the water red."

Several interviewees indicated that the pollution containment facilities observed during our interviews did not exist about 10-15 years ago. Many shipbreaking yards have built storerooms for the paints, black oil, hazardous materials, asbestos and other pollutants that are recovered from the ships, and have installed smoke and ash refining machines. However, when asked about these rooms, the yard manager stated that, "This is for show. We cannot always use them. Due to pressure from the environmental folks, we built those rooms." Managers of another yard stated that "the storerooms built for storing black oil, paint, asbestos and others are rarely used and are for display, as we do not consider those materials as sufficiently dangerous to warrant the rooms and the materials often get sold before they are stored or can be stored." (Asbestos is used everywhere in the localities. Paint and black oils are sold in an open market, and glasswool is sold in Bhatiary. It is not common knowledge that these materials can be health hazards.) In addition, the same yard manager stated that the officials at the DoE often overlook these practices, as people are not aware of their impacts from indiscriminant use.

3.4.1.2 Deforestation

NGOs and researchers have also connected the expansion of the shipbreaking industry to mangrove forest loss along the coasts (Hossain and Islam 2006, Abdullah et al. 2013) and declines in nearby fisheries (Hossain and Islam 2006). In 1989, the total length of shipbreaking yards was 3.45 km, and increased to 12.78 km by 2010. In terms of area, shipyards have increased by 308.7%, from 367 ha in 1989 to 1133 ha in 2010 (Abdullah et al. 2013). Abdullah et al. (2013) noted that the mangrove forests have been declining as more yards are established; however, they do not mention how many yards have been established by destroying mangrove forests. Hossain and Islam (2006) attributed the decline of fisheries near shipbreaking yards without mentioning that the other sources of contaminants may affect fish similarly. A local newspaper recently reported that two yards whose owners were elected parliamentarian were demolished following court directives because 15,000 trees were cut to establish the yard – an example of inconsistent enforcement of environmental protection laws (The

Daily Star, 2014, YPSA website accessed on 01/23/2015). A lawyer from BELA referred to this destruction of mangrove forests to characterize shipbreaking yards as environmentally destructive, stating that “We cannot allow any industry that destroys our environment. There is always a way to economic development. Once an obstruction comes, economic development takes its new course.” He maintained that he does not care if prioritizing environmental protection might lead to the closure of the industry. He was confident that “a way will emerge if this industry will be closed, either in the form of steel imports or others.”

When asked, an official from the Department of Environment stated that “First of all, not all industry has cut the mangrove forests, as few places had mangroves when the yards started operating. Maybe less than 25 percent of the yards were established by cutting the forests. Also, it is important to know that this is not natural mangrove forest; these plants were part of a coastal afforestation program by the Department of Environment launched during the 1990s.” Publications from the Ministry of Forest and Environment did not include Sitakunda as a site of natural mangrove forests (Department of Forest, 2015). Even yearly reports published by the Department of Environment discuss various issues in Sitakunda areas but do not mention deforestation caused by shipbreaking yard activities (Department of Environment, 2015). Additionally, the yards are thought to protect the villages behind them, as the yards are strengthened by stone breakers that are about 400 feet in length. One yard manager mentioned that the shipbreaking activity has ensured safety for the villagers from coastal flooding. While Abdullah et al. (2013) attributes the decline of mangrove forest to the increasing number of shipbreaking yards, YPSA does not specifically mention the decline of mangrove forests due to shipbreaking, -but dedicated only a paragraph on its website for the loss of biodiversity (YPSA, 2015).

3.4.2 Worker safety

NGOs such as the International Labor Organization have consistently presented the shipbreaking industry as dangerous to workers (Bailey 2000, Andersen 2001). Shipbreaking activities require the handling of asbestos and other hazardous materials that can have a cumulative negative impact on human health. The International Labor Organization has dubbed the shipbreaking yards as a “graveyard” for workers (Demaria 2010). Local NGOs such as the BELA and YPSA have been increasingly vocal about the social costs of this industry. For example, on its website, YPSA highlights the casualties in the yards and the meager compensation for the families of the deceased workers (YPSA, 2015). Hossain et al. (2008) conducted surveys to measure existing levels of occupational health hazards in the industry, however through a misrepresentative sampling that only included data and perspectives of injured workers interviewed when seeking temporary medical treatment, not a sample of all workers.

In our interviews, NGO representatives said that yard owners have a high profit margin and that their mentality of profit maximization is the main problem for this industry. They were highly critical of the rate of accidents and the number of deaths in the yards. They asserted that the rate of accidents and number of deaths have not decreased, but rather have increased. They also maintained that environmental conditions have not improved. The NGOs did not consider the introduction of machinery such as magnetic grabs as a significant development. For example, the NGOs considered the building of storerooms for the waste as “eyewash” (for show) that did not reduce the hazardous practices in the yard.

NGOs have conflicting opinions over the standards of treatment of workers with Non NGO actors. An interviewee from a local NGO stated:

> The ways the workers are treated in the yard are not human. They [the yard owner] do not consider them as human. They are abusing these people as they do not get work. Does that mean that we will allow them to die? How can a man remain indifferent to the high number of casualties? It is their mentality that is rotten. They [yard owners] are no longer human; they hunger after money…. They profit from the savings that they have to spend for workers training, medical treatment and others. Day by day the accidents are increasing and so are the deaths. We have our documents, please take we have documented all workers who died of accidents. Of course the available information we have, we do not have the all lists of casualties, and the actual number is even higher.

When asked if the working conditions were improving, he claimed that they have actually worsened.

Conversely, when a yard manager demonstrated how the workers are treated, he showed the workers' dormitories with multiples stories, where they sleep at night and have access to a dining room and kitchen where they eat and cook. He described rent-seeking [bribery] activities of local reporters when asked why yards have restricted entry. He said,

> Most of the local reporters are not well educated and they do not get jobs. Using this news outlet where they work unpaid, they bully us whenever there is an accident, they demand money from us, even the local police demand money from us. If we do not give money, they inflate the news. They do not have any ethics and morality. Look at these workers are working. What risk do you find in there? Okay we have accidents, but tell me where is accident free. Please go the police station in Bhatiary [2 kilometers away] and ask the report of people killed in road accidents every day. I am sure the casualties are a hundred times more than us. Why do they report on accident, why do they not report on our good things? How many people do we employ, where do you get the steel made from these scraps. These people are so mean that they are destroying this business.

Although there are no annual data of number of deaths in the shipbreaking yards, most studies mention that the number of deaths ranges from 279 -400 total since the industry began, with an average of 10 people killed and 150 injured per year (Sujauddin et al. 2014). There are other sources of avoidable mortality in the country that far exceed those that occur in the shipbreaking yards (such as in road traffic accidents) (see Chapter 2). However, the disproportionate responsibility and attention on the shipbreaking industry (from the perception of industry stakeholders) often diverts attention away from these other sources of mortality and morbidity. A representative of a local NGO said, "accidents [in other industries] happens where people die a lot more than that in shipyard, but that does not mean that they [shipbreaking yards] should allow unsafe working conditions." Buerk (2006) also compared the workers' plights in the yards with the working conditions of the garments industry in Bangladesh. He stated that workers in the garments industry in Bangladesh are equally vulnerable and badly paid (Buerk 2006, Smith and Pangsapa 2008). More broadly, these comparisons suggest that policies addressing workplace safety more generally (at the national level) would be more effective in reducing the overall workplace mortality rate than an industry-by-industry approach. However, NGOs may not get as much traction or control over the discourse if they focused their efforts on improving national-scale worker safety laws and enforcement, rather than the more visually suggestive shipbreaking industries (Cairns 2007).

3.4.2.1 Yard safety improvements and worker perspectives

Referring to some of the recent technologies introduced to the yard, for example, the magnetic grab and crane that carry loads instead of workers who, in the famous pictures, are seen carrying heavy metal plates, an NGO official said that “these are eyewash, they do not use that. This is for show. Nothing improves.” When asked about these magnetic grabs, a yard official replied, “Yes, we try to use more than not. This would speed up our work and reduces worker involvement. Look, now we dismantle a ship of 10,000 tons in one month but this would take six months when we did not have this. We have workers reduced by about half by this grab.” While visiting the yards and conducting interviews, the lead researcher also witnessed the grabs in near-constant use.

In the yards, most workers are contract workers. About half of the cuttermen are contracted by the businessmen who have already purchased scraps and need the scraps cut into smaller sections; the businessmen bring workers into the yard and pay by the job. The work injuries and accidents suffered by the cuttermen are unrelated to the work of the yard owners and managers. Thus, the yard owners have distributed some of their liabilities through these middle businessmen.

An official from the Department of Environment who used to supervise the yard said, “This industry has opened my eyes. I have this layman idea that this industry is a bad industry but when I actually visited during my field training in the yard I found that this industry is developed and has become, I would say, semiautomatic." The officials from the Department of Environment mentioned that "We, the Department of Environment officials, consider that the development should be parallel with environmental protection. Look we are [from] developing countries, we have people who need to be fed, and a sound environment does not feed them always."

The workers' responses seemed to lie in the middle; they described work as hard but at the same time, they become happy as incoming ships provide employment. When asked if they had any stress related to their work from the yard owners or officers, some workers said, "No. We take our time; they do not even ask what we are doing. We are relaxed here." One cutter man responded "I work based on my will. When I feel good, I work even fifteen hours at a stretch. If I do not feel like working, I do not come to work even for the whole week." "H," a cutter man working for two years, said that "I worked all night last night and today won't go to work. I work two months then go back to my village and rest for one month and come back. What we earn I give to my family and then come back. This is kind of work that you cannot continue for long." This shows that this work is laborious. One worker, named "B," was found sitting in the yard resting, and said that he had a little injury in his leg and pain. When asked if anyone would punish him as he was sitting instead of working, he said, "The yard people do not force cutters to work as we are paid according to how much we work. They have nothing to do with me." Another worker said that "in our yard we work only eight hours from 8.00 am to 4.00 pm, we cannot work for long times, on an average, a worker works 10-15 years, but most do not do. I try to save money so that I can invest in my village."

One interview was completed with a group of workers working at the bottom of a large ship. When asked if they find this work risky, one of the workers said, "Work here is as risky as the work outside. I have been working here for about five years and now I know what to do. If I am not careful while I am working, I may fall down or a plate may fall on me. When you come for the first time, you do not know what is going on but as the time goes by, people get to know how to deal with these things." I asked if he saw anyone killed or injured, and he said, "yea, I hear about people injured and killed, but I have never seen anyone killed since I have started this work." When asked if anyone in his group has suffered injuries, he said, "Injury is nothing, this is iron and you deal with that. So you will get cut almost every day, that's normal. But thank God, none died since we are working together." He added that, "People used to be killed about ten years ago. Things have improved a lot since then." I asked if he was satisfied with his salary. He said, "I get about 500 taka (about 6.5 USD) a day but this is high for me as I am a skilled worker but, he (a man standing beside him) gets somewhere around 300 taka (4 dollars). Where I would get this much? Moreover, if you are day laborer outside, you may have work today, then you do not have work tomorrow."

Workers also disputed a common NGO perspective that workers were not supplied with proper safety equipment. One NGO representative said that "They [workers] get a low salary. They are not given safety clothes. There is nothing that improves working conditions." Our observations in the yards revealed that cutter men (but not other types of workers) routinely wear safety clothes, boots and goggles because they were aware of the risks from the wielding torches, and identified them as potential causes of immediate injury. The workers clarified that "these safety clothes are not given from the yard; but that we are expected to provide them ourselves and we are not forced to use them." When asked what happens if they are injured at the yard, one stated that "I went to a pharmacy for free medicine. There is a doctor in our yard who comes sometimes and takes care of our injury and gives medicine." Regarding the safety clothes, one yard manager said that "they have all of the clothes available but the workers cannot work long hours wearing them because they are heavy and make them tired."

3.4.2.2 Enforcement of safety regulations

Regarding accidents, a yard official said that "after the ships arrive at the beach, several government departments [Ministries of Shipping and Labor, Department of Environment and Department of Explosives] come for inspection and certify that the ships are fit for breaking." However, after this inspection the yard owners use a technique to confirm the availability of oxygen inside the ships: "We send a healthy chicken inside for few days to see if the chicken can survive, which testifies that there is not a shortage of oxygen inside the ship. In addition, during work they always make available the oxygen cylinders." He also mentioned that "before we start cutting, we adopt some precautions. We keep foam oil or fire resistant oil near the cutter." He complained that "the inspection department does not have the appropriate machine that can correctly measure the presence of the toxic chemicals and the oxygen level." He maintained that "there are two steps that need to be ensured. First, government department officials need to be well equipped and well trained, and then the shipbreaking association needs to have a team trained to properly use meters to measure the presence of toxic gases." Thus, the ships that are brought for dismantling need to be cleaned beforehand and then need to be rechecked once beached in order to ensure that the ships are free from all toxic gases.

On YPSA website the procedures taken by the yard officials are acknowledged. However, they do not acknowledge the issues associated with government departments and with the lack of enforcement of international regulations. When asked how workplace accidents can be avoided, a YPSA official said, "first of all, it is the mindset of the yard owners that needs to be changed. They can improve things if they want to. But they do not want that. We recommend that worker training must be ensured and the compensation of the injured and deceased workers need to be increased and ensured." An official of the Ministry of Industry (named "S" here) acknowledged the need for worker training and mentioned that they are discussing the issue with yard owners; soon, they will launch a workers' group that will be trained and supplied. However, "S" was critical about NGOs' claims of accidents and number of deaths: "Go to the garments industry; go to the International Labor Organization [ILO]. They have their data that proves everything. We have much fewer casualties, much less. Why are they [NGOs] so vocal, what is their interest? Even after that we are going to a worker pool that will train the workers for the inside cutting."

3.4.3 Funding, bias, and industry growth

Most of the non-NGO actors referred to the funding dependency of the local and national NGOs on international organizations to explain what makes them cautious about commenting on improvements in the shipbreaking industry. One interviewee stated, "Why does the NGO work? Who funds the NGOs? Please investigate the matters; you will see that most of the projects are internationally funded." The official of one NGO concurred with this perception of their funding stream: "It is hard to say exactly how much of our projects are externally funded, but mostly are from US, EU, Japan and others. Almost 60 percent are from abroad and some 20 percent are nationals and the rest are our own."

When NGO officials were asked about their data collection methods, and if they have any indication that reporters, journalists and others demand money from the yard, he said, "I would not say that. But as you know that is a common picture of Bangladesh and that they may have done this. Even researchers do; I know of one who has produced reports that looks like shipbreaking is a very good industry, he took money from the owner. Our people cannot do this, you know if one does, then one never can write the actual scenario." There was also a difference in opinion regarding the growth of the number of yards. NGO officials said that "the actual yard number is increasing." However, the yard officials said that "the yards are decreasing to about 50. It is going to stop at some point if such image distortion is going on."

3.5 Conclusion

While study respondents shared concerns about environmental contamination from the shipbreaking industry, many raised concerns regarding the lack of proper data collection methods that could measure the sources of contaminants appropriately, although a few (including NGOs representatives) argued that shipbreaking contributes the majority of the pollution and that other sources are insignificant. However, until adequate data are collected to determine the share of pollutants originating from different industries, these statements contain significant uncertainty. This uncertainty calls for a national-scale investigation of pollution levels and sources, rather than an industry-by-industry process.

Non-NGO actors generally believed that the yards have improved over time. Non-NGO actors also believed that the causes of the accidents are mostly explosions due to the presence of toxic gases, which can be eliminated if existing international regulations are enforced, such as the Basel convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (or "Basel Convention"). Most of the interviewees believed that enforcing the Basel Convention (binding ship owners to pay for clean-up actions prior to dismantling) would reduce the chances of most accidents, while a minority of the respondents instead believed that the yard owner's responsibility for these conditions outweighs the ship owner's responsibility (consistent to the findings of Muhibullah, 2014).

NGOs often gain moral authority and control of the discourse through showing their concerns for the number of deaths and injuries in the yards. Despite their hard jobs, the worker interviewee said they become happy when they see new ships are beached, as this guarantees a job for a few more months. This is reminiscent of Peluso's (1994) remarks that peasants have their own culture, need preferences and demands that are most often determined by the access to available opportunities. Buerk's (2006) ethnography of the shipbreaking industry in Bangladesh captured how workers recalled their helplessness over the abysmal economic plights their families experienced. He stated that "Young men…hung around all day...not much hope of finding any [work] in the fields or village shops" (Buerk 2006 p 76-78; see also Moore 1993, Cairns 2007). The employment that the shipbreaking industry provides is an important benefit to local and regional communities that cannot be dismissed.

The difference of opinion between NGO and non-NGO interviewees illustrates the differing constructs of local problems and solutions (Zimmerer and Bassett 2003). NGOs generate powerful discourses through reports to the media that support some actors while marginalizing others. The workers' rights issue provides a powerful narrative, and NGO actors have used this narrative in interviews on CNN and the BBC, during participation in international conferences, and for access to multiple international environmental organizations such as Greenpeace, NGO Shipbreaking Platform, The International Freedom for Human Rights (FIDH) and others. These international organizations depend upon local expertise for information and authenticity. Local organizations take advantage of this information dependence and produce knowledge that will be appealing to international organizations. At the same time, local and national NGOs tend to be cautious with their actions that may oblige international parties.

The exclusive focus on yard-based solutions detracts attention from national and international policies that will solve environmental and worker safety problems more effectively (Chapter 4). From the summary of different stakeholder interviews, we suggest that the solutions lie at multiple scales: 1) national-scale policies that track pollutants from all industries, employing appropriate logistics, and the enforcement of existing pollution regulations through relevant government inspection teams and authorities; 2) national-scale policies regarding worker safety that would be applied evenly across all industries; and 3) global scale policies (e.g., Basel Convention, or the new Hong Kong Convention for the Safe and Environmentally Sound Recycling of Ships) that require ship owners to clean dangerous and toxic substances from the ships prior to being dismantled.

The publicity around yard working conditions by the international NGOs has been critiqued by Cairns (2007), calling this a "Western critique of a Western problem" (p 269). Cairns (2007) argued that the negative image of the shipbreaking industry reflects the Western (globally dominant) notion of "badness" (p 266); in this context, badness is a relative, subjective term that viewers from developed countries would conclude based on their own set of environmental ethics; this notion of badness is different in a developing country context (Tucker 1999). Cairns (2007) argued that this industry should be viewed through the lens of “constructive ambivalence,” meaning that the industry has a problematic nature but that needs to be seen from the local perspective, while being mindful of the global context.

The multiscale dimensions of shipbreaking activities provide an important contemporary case study to the political ecology literature. This study demonstrates that if we fail to consciously and systematically address the multiscale dynamics involving different stories, and differences in whose story is given the loudest voice, global environmental solutions will be hampered by distorted attention some scales over others (Princeton et al. 1994; Cash and Moser 2000).

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Chapter 4: Policy gap analysis of Bangladesh Shipbreaking Industry[6]

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Abstract

A challenge faced by the ship breaking industry in Bangladesh is to balance economic goals with improving environmental and human health conditions. Since ship breaking is an inherently international industry, Bangladesh as a major shipbreaking party needs to adjust its national policy strategy to harmonize with international rules, regulations, and decision making. The Hong Kong International Convention on the Safe and Environmentally Sound Recycling of Ships (HKC) and the Basel Convention on the Control of Transboundary Movement of Hazardous Waste and their Disposal (BC) regulate how ships are sold, managed, traded, and scrapped. Here we use a policy gap analysis to determine whether and how current Bangladesh national policies conform with international shipbreaking conventions and to identify gaps in regulatory attention. We used key informants' interviews to obtain expert opinions on existing policies and a grounded theory approach for data analysis. Although national laws do conform with international conventions, Bangladesh authorities are currently not able to fully implement either national or international regulations as they lack the necessary financial and technical capacity for monitoring and enforcement. We

[6] This version will be submitted to *Journal of Policy analysis*

recommend that, in accordance with the "polluter pays principle," the international shipbreaking policy regime should utilize a deposit-refund system to rectify the lack of capacity in developing countries to comply with regulations. By our initial estimates, a global fund adequate to upgrade all facilities in India, Bangladesh and Pakistan (to recycle the current flow of end-of-life ships) could be fully financed by a deposit of ~0.3% of a new ship's purchase price per year.

4.1 Introduction

Ship breaking is an inherently international phenomenon, wherein international and national actors are linked via ocean-going ships that are owned, operated, and disposed of transnationally (Elliott 2004, Karim 2009, Karim 2009, Frey 2013, Galley 2014). Global environmental governance enforces common expectations among these actors through the production of shared norms, rules and procedures (Haas 1980, Keohane 1982, Haas et al. 1993, Raustiala 1997). With regards to shipbreaking, the Hong Kong International Convention on the Safe and Environmentally Sound Recycling of Ships (HKC) and the Basel Convention on the Control of Transboundary Movement of Hazardous Waste and their Disposal (BC) promote high expectations for worker safety and environmental conditions across all nations (Sundram 1997, Moen 2008, Matz-Lück 2010, Puthucherril 2010).

National governments remain important actors for this industry, as they are responsible for implementing these international legal frameworks as put forward by the global governance on shipbreaking (Raustiala 1997, Elliott 2004). While states decide to sign and ratify the global conventions, there is no guarantee that states will fully implement them, as implementation is based on the states' discretion (Chayes and Chayes 1993, Bernstein 2002, Avdeyeva 2007). Such discretion is often founded on the availability of the state's resources to implement regulations, and their legal and administrative ability to monitor the observance of such regulations (Young 1989, Victor 1998, Najam 2005).

Bangladesh adopted the Ship Breaking and Ship Recycling Rules (SBSRR) of 2011 in response to the HKC. This rule came to the order of the High Court of Bangladesh in a writ petition no. 7260, 2008 by the Bangladesh Environmental Lawyer Association (BELA). Other pre-existing national laws also address environmental protection and worker safety more generally. Despite this regulatory conformity, several policy studies on the Bangladesh shipbreaking industry identify numerous policy implementation challenges for the Bangladeshi government, including inadequate legislative framework, capacity limitation and lack of proper inspection/authorization systems (Karim 2009a, Karim 2009b, Alam and Faruque 2014). Using the policy gap analysis methodology of Dongol and Heinen (2012), we reviewed treaties and policies relevant to the shipbreaking industry at the international and national scales, and interviewed those directly involved in the shipbreaking industry and its oversight in Bangladesh. We analyzed the interview results using grounded theory and identified policy gaps where existing policies need better enforcement or where new policies are required to ensure successful implementation. We recommend improvements to these international conventions based on the "polluter pays principle", a widely held ideal in international environmental governance (Georgakellos 2007). The principle guides policy-makers to place the burden of safeguarding humans and the environment onto polluters, who must cover the costs of mitigating harmful activities and market externalities.

4.2 International policies

4.2.1 Basel Convention on the Control of Transboundary Movement of Hazardous waste and their Disposal 1989

The Basel Convention (BC) was adopted in 1989 under the auspices of the United Nations Environmental Programme, and later entered into force in 1992, in the face of growing international traffic of hazardous wastes to developing countries (Puthucherril 2010, Mikelis 2012). The purpose of this convention was threefold: to minimize the generation of hazardous waste; to enforce 'proximity principles' (the disposal of hazardous waste carried out close to the point of production); and to promote sound waste management facilities (Puthucherril 2010, Selin 2010). This convention empowers exporting states by granting them the ability to cancel contracts when they suspect that the importing state does not have the proper capacity to manage the waste (Karim 2009, Galley 2014).

Article 4 of the BC assigns responsibilities to exporting states regarding the assurance of sound handling and treatment of waste. Article 11 permits parties to form bilateral, multilateral and regional agreements with nonparties despite the prohibition of waste transfer between the parties and nonparties. Galley (2014) considers this permission to be a weak point for the convention as the economically strong countries may coerce weak states to circumvent the ban. An interesting development unfolded when a total ban amendment was agreed to but not enforced at the second meeting of the Conference of the Parties of the Basel Convention in 1995. The ban amendment prohibits the movement of hazardous waste from Organization for Economic Co-operation and Development (OECD) to non-OECD countries but does not influence its movement among OECD countries (Sundram 1997). Although this ban amendment has not entered into force (except in the European Union, unilaterally enforced through European Waste Shipment Regulation No 1013/2006), it acknowledges that the waste flowing from developed to developing countries (without protection of developing countries' health and environment) is illegitimate (Moen 2008, Selin 2010, Mikelis 2012, Roe 2013).

The applicability of the BC to end-of-life ships is controversial (Mikelis 2012, Ormond 2012). From the shipping industry point of view, by definition a ship cannot be waste if it can operate in the ocean (Bhattacharjee 2009). However, according to the convention's proponents, a ship can be both a ship and hazardous waste depending on the intent of the owners; if one declares an intent to discard a vessel for scrapping, the ship is waste (Moen 2008). Usually, ship-owners decide to scrap a ship when they are operating in international waters, away from state jurisdiction. Thus, ship-owners obscure the intent to scrap ships to avoid complications and costs (Galley 2014). The other challenge to reducing the traffic of transboundary movement of ships as waste is the frequent change of ship ownership, which obscures ownership through open registration from a nonparty state where owners are allowed to be anonymous. Galley (2014) opined that the intention of discarding is less important than the location where the decision is made, as the decision to discard the vessel in the middle of the ocean is beyond the jurisdiction of any state (hence the need for international treaties).

4.2.2 Hong Kong International Convention on the Safe and Environmentally Sound Recycling of Ships, 2009

The ambiguous jurisdiction of the BC over ships as waste led to The Hong Kong Convention for the Safe and Environmentally Sound Recycling of Ships (or "HKC"). The HKC was initiated in 2009 and was set to take effect in 2015. To take effect, the convention needs to be signed by no less than 15 states that constitute no less than 40 percent of global merchant ships gross tonnage, and by those countries that dismantle ships at no less than three percent of the total global gross tonnage (Article 1.1, 1.2 & 1.3). This convention specifically introduces rules and procedures to improve shipbreaking facilities, and thereby resolve the dilemma posed by the BC of defining ships as waste (CIEL, 2011).

The HKC aims to improve Ship Recycling Facilities (SRF) through the exchange of information regarding environmental and worker safety issues among stakeholders. For example, the HKC directs SRF to "prepare a ship recycling plan (SRP) that includes policy ensuring workers' safety and the protection of human health and environment, and the procedure to prevent explosions, fires, and other unsafe conditions by establishing conditions for safe-for-hot-work throughout ship recycling" (Reg, 18.1&19.1). The SRF shall ensure that "all hazardous materials detailed in the Inventory are identified, labelled, packaged and removed to the maximum extent possible prior to cutting by properly trained and equipped workers, ensuring the use of personal protective equipment for operations" (Reg, 20.2&22.2). An SRF needs to have an SRP approved by the recycling state, which would then notify the approval to the flag state, the ship-owners and the SRF (Reg 9.5).

Under the HKC, both ship-owners and recycling states perform reporting activities (Rossi, 2009). Ship-owners will notify "in writing of the intention to recycle a ship in order to enable the Administration (importing state) to prepare for the survey and certification" (Reg, 24.1), and owners also need to provide a finalized inventory of hazardous materials to help prepare an SRP by the SRF (9.1). With approval from the recycling state, the flag state – the state that registers an end-of-life ship, not the citizenship of the owner – must conduct a final survey to check if the inventory is correct. Ship-owners must also approve the surveys and certification of the end-of-life ship (Reg, 10.4&11.11; Chang et al. 2010, Matz-Lück 2010, Fang and Mejia Jr 2012, Mikelis 2012).

The HKC has attracted considerable scholarly criticism. The possibility of this convention coming into force is uncertain because of its entry requirements for signatories (Chang et al. 2010, Ormond 2012). According to the entry requirements, at least one of the southern recycling states needs to sign the convention, as all of the OECD countries (plus Turkey) do not constitute 3% of the total recycled gross tonnage from ships. With the exception of China (which has an existing legal framework and improvements to meet HKC requirements), Bangladesh, India, and Pakistan are expected to have reservations signing the convention as they are currently far from meeting the standards stipulated by the HKC (Chang et al. 2010). The HKC was to come into force in 2015, but as of this writing, there are only three countries (Democratic Republic of Congo, France and Norway) signed as contracting parties; Bangladesh has not yet ratified the HKC (IMO 2015).

The HKC does not attempt to correct the global ship-registration system that makes identification of the ship-owners impossible, and this lack of oversight will have a trickle-down effect to all notifications and reporting requirements (Brunnee 2004, Gupta 2008, Chang et al. 2010, Cherry and McEvoy 2013, Frey 2013, Galley 2014). Instead, the HKC utilizes a voluntary approach for southern countries by not forcing them to change beaching methods which, some argue, are incompatible with the objectives of the HKC (Chang et al. 2010). The HKC also does not deal with the waste management and safety issues after the scrapping stage, ending with metal processing for household products and rerolling for construction sectors. Most importantly, the convention does not follow the polluter pays principle (Georgakellos 2007), as there is no liability regime that obligates the polluters and violators to compensate for resulting pollution in the shipbreaking nation (Puthucherril 2010).

4.3 National policies

4.3.1 Bangladesh Environment Conservation Act, 1995

The Bangladesh Environment Conservation Act of 1995 (BECA) provides the strongest legal instrument to prevent environmental pollution. Section 6D of the Amendment Act passed in 2010 specifically deals with ship breaking, requiring that the owner and importer of ships and the users of ship breaking yards not cause any pollution and health hazards during the scrapping process (Karim 2009). The Department of Environment is responsible for enforcement of the BECA. The Amendment Act (2010) outlines the penalties for violators. The Violation of Article 6(D) requires a violation penalty of no more than two years of jail and/or no more than 200,000 taka (about 2400 USD) for the first offence. For each of the subsequent offences, punishment ranges from a minimum of two to ten years in jail and/or two to ten hundred thousands of taka (2400-12000 USD). Under the companion Environmental Law of 1995, every industry, including ship breaking, must obtain an

"Environmental Clearance Certificate" from the Department of Environment in the Ministry of Forest and Environment (Karim 2009).

4.3.2 Labor Act, 2006

The Bangladesh Labor Act of 2006 (BLA) was promulgated on the 11th October, 2006 with technical assistance from the International Labor Organization. The BLA outlines conditions of service and employment, health and hygiene, safety, welfare, working hours and leave, wages and payment, workmen's compensation for injuries in workplace accidents, worker participation in company's profits, and provisions for collective bargaining agents. Several sections delineate comprehensive procedures and set standards for working conditions. Unlike the Ship Breaking and Ship Recycling Rules of 2011 (see next section), the BLA incorporates a collective bargaining authority delegated to the workers and includes standards for employment benefits and wages. In the BLA, parties are penalized for acts of noncompliance which result in accidents, however it does not mandate the presence of doctors or free medicine coverage to avoid unnecessary delays leading to further injury or illness.

4.3.3 The Ship Breaking and Ship Recycling Rules, 2011

Bangladesh drafted the Ship Breaking and Ship Recycling Rules (SBSRR) in 2011, after the High Court directed in writ petition No. 7260 by BELA (an environmental lawyer association which filed lawsuits based on reported environmental degradation) in 2008 that the government needed to enact policies that will ensure environmentally sound shipbreaking. The 56 page SBSRR consists of detailed procedures for the inspection and approval of incoming vessels by several government authorities as members of a Ship Building and Ship Recycling Board (SBSRB), chaired by the Ministry of Industries. Chapters II through V detail certification processes for beaching, recycling, hazardous waste management and environmental compliance. Chapter VI describes the actions performed by the SBSRB, which include improved training facilities (23.5) and identifying a model ship recycling facility (23.4.ii). Finally, Chapter VII elaborates upon the management of occupational safety and health issues. Through the SBSRR, shipbreaking has been brought under the purview of the Ministry of Industry, which will monitor imported ships destined for recycling (Article 1.2). Each departmental member of the SBSRB is in charge of defined tasks, and will carry out inspections and issue certificates in their respective areas to the yard officials. The SBSRB will issue a No Objection Certificate (NOC) after verifying all of the documents issued by the different departments. This NOC will allow yard officials to open a letter of credit to import retired ships.

Regarding the ship recycling process, the SRF plan ensures:

- the existence of temporary storage of hazardous and non-hazardous waste materials,
- asbestos handling and removing facilities,
- sanitation and rest room facilities for a minimum of 50 workers,

- firefighting facility and emergency response systems including an oil spill combat system, and personal protective equipment, and
- a system documenting the number of trained workers.

The SBSRB inspects yard facilities every five years and issues certificates within thirty days of an inspection (Article 15 III). During the process, the yard owners must show the presence and use of an explosive gas detector and an oxygen percentage analyzer in the yard (Article 15 VII). Secondly, the yard owner must possess a ship recycling plan, which includes the specifications of incoming ships, a hazardous waste assessment, personal protection equipment availability, and certification of "fit for hot work." The plan also ensures that the exchange of ballast water is completed outside of the national waters boundary.

The rules also contain penalty provisions for any violations of rules in the yard. Article 45.3 states that in the event of an accident/fire/explosion leading to death or serious bodily injury, the yard owner will be suspended for one year with a monetary penalty, from one lac to ten lac taka (1200 -12000 USD). The closest kin of the deceased and injured will be compensated five lacs and two lacs (6000 and 2400 USD) respectively (Article 45.3). In addition, the penalty for fraud and false information, the employment of uncertified workers, and workers without proper personal protective equipment, is 1 lac, 50 thousand and 25 thousand taka (1200, 600 & 300 USD) respectively (Article 46).

4.4 **Methods**

The lead author interviewed 13 key informants at the national level including key government officials in charge of the ship breaking industry (2), environmental officials (4), representatives from national NGOs (2), ship breaking experts (3), and university professors (2). The interview questions focused on the challenges that Bangladesh faces for the improvement of worker safety and environmental conditions, and their suggestions for improved practices and policy implementation. A few interviews were formal and structured, however most interviewees were only willing to talk off the record. The interviews were conducted during field visits from May 2014 to August 2014 and from December 2014 to March 2015 in Dhaka and Chittagong, Bangladesh. Key informants were identified in two ways: identifying key officials from government telephone directories, and through snowball sampling. For example, shipbreaking experts and university professors were suggested as contacts by government officials from the Ministry of Industry, who were in turn identified by NGO officials. Following a grounded theory approach, the lead researcher wrote daily memos to synthesize the interviews and coded the memos in terms of the key words that supported theoretical and categorical terms (Dongol and Heinen 2015). The interviews were conducted in Bangla and, later, translated to English. The lead researcher also reviewed documents, especially court directives that bind government officials to comply with international treaties and national laws.

4.5 Results

4.5.1 Lack of equity principles in international treaties/ Cost of compliance

Almost all of the government officials acknowledged that international conventions are not equitable. Without offering any sound financial and technical assistance, waste and pollution conventions routinely violate the polluter pays principle. One official who is working with the International Maritime Organization (IMO) in a research project stated:

> The international treaties usually do not represent the interests of developing countries. There are international politics that use those institutions for the spread of their own interests. See World Bank, IMF [International Monetary Fund], etc. and you will find that logic. Even for shipbreaking, see how the treaties have been useful. Why are ship-owners in HKC undetected? Or not attempted to be detected. They have shown no attempts to hold them. They employ treaties to improve our recycling states… that's weird… yes, we [those associated with a project that is developing a model yard in Bangladesh with financing of a Japanese organization] are trying to do our own way… trying to manage a fund [for spending yard upgrades and research]. Japan is funding and we are trying to communicate with them so that they are interested to develop our yards.

Another top official from the Department of Environment (Chittagong) stated that: "We attend the international conventions, but our voice is rarely heard. We take a soft approach… try to bargain, but you know… a lot of factors are there that do not allow our voice to be heard. But still we try to comply." These responses provide evidence that they do not think shipbreaking treaties are equitable and hence, feel discouraged against full commitment, although without becoming fully deviant (there is some attempt to comply).

4.5.2 Administrative capacity of implementing agencies

Administrative capacity means the ability of the officials to deliver services to the people within task areas (Sarker 2004). About 50 percent of our key respondents mentioned a lack of administrative capacity. "New," "frequent transfer," "posting instability," and "lack of funding" were some common phrases that reflect the lack of administrative capacity of government agencies. The key official from the Ministry of Industry explained, "When I was new to this Ministry, I went to attend an international conference. I can remember I was in dark about what is going on in shipbreaking. I worked really hard to collect all the necessary information about shipbreaking. I studied day and night in wherever I get time… in office and in house in order to gain sufficient confidence to represent the country." This response indicates inadequate knowledge, which becomes worse with frequent changes of government postings (Sarker 2004). While this has an influence on public service delivery, this also suggests a key gap in enforcing international conventions and one of the important ways that the actors/representatives of the developing countries demonstrate a lack of bargaining power (lack of information) when treaties are written.

Fisher and Green (2004) outlined three ways that developing country actors may be disenfranchised by the treaty process: lack of endogenous resources in terms of training and communication such as language; lack of transnational connectivity reflecting in-depth knowledge about the environmental issues; and low geopolitical status that determines the importance of a state in relation to other powerful states. One additional (but often overlooked) resource is institutional or organizational memory regarding implementation and enforcement practices. One officer stated that "Very few officers work hard. Most of them do not care about [this]. Why would you do that? Think. You have gathered knowledge today, your transfer order coming tomorrow. I may not be here in next month".

Regarding this matter, a yard manager said, "Inspection teams come and give us the gas free certificate from the Department of Explosives. But, they do not have the appropriate equipment to measure. We have better [measuring techniques] than what they have. The capacity of the Government Departments need to be increased… otherwise, you see no change." This reinforces the point regarding the lack of proper capacity of the agencies in charge of inspection.

4.5.3 Commitment of implementers

Three respondents (who work in different administrative agencies) reflected on the level of commitment of the implementers. One government official at the Department of Environment stated, "It is we who have provided all documents to BELA and urge them to file lawsuit to the High Court, so that we can work by the directives of the honorable High Court." Officials from the Department of Environment were eager to enforce regulatory compliance, but the lack of political will discouraged or prevented them from doing so.

The lack of commitment by another government department [Department of Inspection] resonated in the comments of an expert on the Bangladesh shipbreaking industry. He asked, "Did you read ship breaking rules in 2011 [Ship Breaking and Ship Recycling Rules 2011]? This is a good policy… sets the plans and procedures, which if followed, will improve the yard….but you know there are other problems, especially in execution and supervision. The inspector does not have appropriate testing instruments; you need to measure oxygen level, you need to measure existence of other gases, but where is your equipment?" He stated, "Very few inspectors actually physically visit the ships. For example, officers go for inspection when ships are at high seas. In high seas, ships are needed to inspect if the inventory list is present and if the due certification exists. Very few inspectors actually go. Going there is a hurdle. Only way you can go is with small navy boats. In high tide you sometimes get wet, it's risky. So what is the point someone will go and provide report? Even I went few times. These all need to improve in order to enhance monitoring and compliance."

4.5.4 Ideological difference

About 70 percent of the respondents supported an approach to development that balanced environmental and economic goals. One interviewee from the Department of Environment stated: "Environment and development is our goal; we do not want environment only. That does not feed us. We need economic development too. They think that we are poor country. Our people starve. We need work. When we consider the environment we consider it so that industry does not hurt." More than half of the interviewees did not believe that ship breaking was polluting as much as other industries, and believed that ship breaking methods are improving day by day. A similar view was echoed by the Ministry of Industries officials; they wanted to see shipbreaking be economically strong and emerge as a viable industry. In a developing country, this perspective bears significant implications. While the human rights and environmental conditions are important, economic development is also an important consideration for both workers and policy makers. This is in conflict with the underlying assumed values of international treaties such HKC, which provides for sound recycling that protects environment and workers but ignores the economic realities of the activities that allow recycling industries to continue (see Chapter 1, Chapter 3).

4.5.5 The nature of institutional context

Noncompliance appears in how the state prioritizes its time, effort, and resources for some areas rather than others. In Bangladesh, the ship breaking industry has been brought under the Ministry of Industry with its key officers at a rank of joint secretary. One high-ranking official said, “We are seriously missing resources and manpower to improve the situation. But here are lots of problems. Political unrest diverts most of our attention, which needs to be addressed and resolved. Those problems are urgent and require immediate attention. Much more severe than the ship breaking.” [This comment was offered in a different context referring to NGOs, and why they are more vocal on shipbreaking issues than political issues, where daily mortality rates are higher and actions cripple the country economically.] Another government official said, “We have administrative constraints and pressures from government that sometimes [make us] slow down and provide space for the businesses…. Businessmen have ties to the political person. They sometimes exercise political power.” One NGO representative stated, “Ship breaking was not officially recognized as an industry until 2013 and was under several government ministry and departments; Department of Environment under the Ministry of Environment and Forestry, Department of Customs, Department of Explosives, etc. No coordination among them existed whatsoever. Things happen when you are under many departments; you are actually under nowhere.”

4.5.6 Absence of financial and technical assistance

Almost all government officials mentioned that financial resources were a main limiting factor for improving ship breaking conditions in Bangladesh. Comments by one official from the Ministry of Industry resonated such constraints: "We have some constraints to work as the work requires funding. We are waiting for Japan's project on Ship Breaking [Japan International Cooperation Agency (JICA)]. In fact, they came forward to invest in our country, but due to some technical problems, we could not respond to that fund. Now, JICA is funding to develop India Ship Breaking." (This is a different Japanese-funded project than the one discussed in Section 5.1.) Besides the demand for technical support, the comments reflect the expectation that the convention will come forward to support the development process. The official expressed discontent over the conventions regarding the lack of any financial mechanism to improve yard conditions. The official explained, "The conventions reflect how the developed countries interests are served through such international conventions. Ship breaking is a service for them and they are earning a lot of money but this convention does not require them to invest it in the yards."

4.6 Policy gaps: regulatory and compliance implications for Bangladesh

Compliance is a spectrum starting from persuasive to coercive compliance (Young 1997, Avdeyeva 2007). Generally, the persuasive model of compliance emphasizes a problem solving approach to various sources of compliance problems, including (1) issues with international treaties, (2) capacity limitations of states, and (3) uncontrollable social or economic changes which lead to non-compliance (Chayes and Chayes 1993, Downs et al. 1996, Weiss and Jacobson 2000, Tallberg 2002). The coercive model of compliance focuses mainly on the formulation of a liability regime, through identifying defectors and imposing penalties for defection such that the cost of noncompliance outweighs the cost of compliance (Murphy 1994, Mitchell 1998, Tallberg 2002). These compliance models provide a rationale behind the existing gaps in policy development and implementation that we found in the policy regime for the shipbreaking industry in Bangladesh.

Table 4.1 describes the areas of regulation and compliance that the two international treaties and three national laws address (or fail to address) related to the shipbreaking industry. Unclear ship registration systems (obscuring the ownership of retired ships), ship inspection systems, and workers empowerment laws were identified as major oversights of the shipbreaking policy regime by the policy review. Assistance from other states and beaching in non-signatory countries are addressed in HKC, but without mechanisms to ensure that these regulations will be enforced and yards will be upgraded. Assistance for upgrading yards is also missing from the SBSRR. The SBSRR does address administrative capacity and worker training, but without incentives for compliance.

4.6.1 Gaps in regulations

One issue with the international treaties involves a faulty ship registration system which obscures the identity of ship-owners or other authorities that can be held accountable for non-compliance (Table 4.1). Both the HKC and BC neglect to provide comprehensive procedures to identify the ship-owners so as to detect treaty violations. The lack of detection is often a large source of non-compliance (Young 1989, Murphy 1994, Mitchell 1998, Brunnée 2004). This gap was apparent in both the interviews and in the policy review. Some analysts consider this as a serious weakness of international waste treaties (Bhattacharjee 2009, Chang et al. 2010, Fang and Mejia Jr 2012). In addition, this gap looms large in the national policies as well, as the technical assistance provision has been largely made voluntary. The voluntary nature of financing seriously undermines particularly the legitimacy of HKC in the recycling states, as the recycling states believe that polluter pays principle is closely linked with capacity development.

Table 4.1: International and national regulatory gap analysis regarding shipbreaking in Bangladesh, in order of policy implementation stages. Section numbers indicate that gaps were identified by key informants (see sections of chapter for further context). X = regulations exist but are unable to contain noncompliance X (A)= identified by Authors review, X (I)= identified by interviewee; Blank cell: gap exists due to absence of regulations; N/A= irrelevant. * denotes if the treaties are in force.

	INTERNATIONAL TREATIES	*NATIONAL LAWS*

	BC 1992*	HKC 2015	BECA* 1995	BLA* 2006	SBSRR 2011
Regulations					
Clear ship ownership (Section 5.1)	X (A & I)	X (A&I)	N/A	N/A	X (A)
Beaching ships in non-signatory countries	N/A	X (A)	N/A	N/A	N/A
Ship inspections (Sections 5.2 & 5.3)		X (A&I)	N/A	N/A	X (A)
Government agency or ministry with clear enforcement mandate (Section 5.3)	N/A	N/A	X (A)	X(A)	X (A& I)
Assistance from other recycling states (Section 5.6)	X (voluntary)	X (voluntary)	N/A	N/A	N/A
Collective Bargaining Authority	N/A	X (A & I)	N/A	X (A)	X(A & I)

	Penalties for yard facilities					X
	Penalties for ship owners	X	A & I			
	Penalties for signatory countries			N/A	N/A	N/A
Compliance/Capacity building mechanisms						
	Sufficient administrative capacity and resources (Section 5.2)		X (A&I)			X(I)
	Committed enforcement officers (Section 5.3)					X
	Incentives or support for yard upgrades (Section 5.6)	X (voluntary)	X(A & I)	N/A	N/A	X(I)
	Training of workers					X

Neither the HKC nor the SBSRR discuss any restriction on “beaching methods.” Some scholars believe that it is impossible to increase environmental protection unless beaching is eliminated as a breaking method, using properly constructed ports instead (Fang and Mejia 2012). Workers’ empowerment was another important issue that came out in the interview responses but is largely ignored at the international level. It is not entirely clear if workers will be empowered through enhancing bottom-up organization, or if a top down approach would be more effective. The Collective Bargaining Authority for workers is discussed in BLA, but is largely ignored in both HKC and SBSRR.

4.6.2 Gaps in regulatory compliance

Strengthening the inspections at different stages of retirement and beaching of ships is mentioned in both HKC and SBSRR, but the capacity of the inspection teams was not addressed; the weakness of inspection systems was identified by the interviewees as a key regulatory shortcoming. Indeed, capacity limitation was commonly discussed in the domestic interviews. Various key informants identified this problem as a challenge for the national government to elicit compliance (Table 1). These challenges included a lack of administrative capacities, lack of implementers’ commitment, lack of sophisticated logistics and lack of technical assistance. States often identify poorly designed policies as those that ignore the states’ varying levels of ability and resources to comply with international treaties (Chasek et al. 2013). Indeed, it is the demand of most of the developing countries that sufficient provisions for financial and technical assistance are provided for improved compliance. The current regulatory regime for shipbreaking has deviated from the globally accepted polluter pays principle (Puthucherril 2010, Rossi 2010, Ormond 2012, Galley 2014). The HKC fails to attribute liabilities for retired ships to the ship-owners (Brulle and Pellow 2006, Puthucherril 2010, Chasek et al. 2013). The nation states feel discouraged to commit to such international agreements when the underlying principles are not upheld, increasing the likelihood of noncompliance (Haas 1980, Keohane 1986, Ross 1998, Risse and Sikkink 1999). Our study indicates that implementation (and compliance) is reduced by both a lack of administrative capacity, and when the ideological orientation of the implementers is incompatible with policy norms. In this case, key policy implementers in Bangladesh think that shipbreaking laws should consider economic development along with environmental protection, not just environmental protection per se.

While international law seems to utilize persuasive compliance with little provision for capacity building measures, the SBSRR uses coercive strategies by stipulating punishment/penalties for defections, mainly in the event of accidents or injuries. To enhance supervisory oversight, a compliance officer has been assigned to every yard to ensure the safety procedures and presence of safety logistics and facilities (Table 4.1). However, the SBSRR does not address the lack of commitment of the government officials and deficiencies in administrative capacities. The main officials from the Ministry of Industry mentioned training for workers but did not discuss the critical need for worker empowerment and security, as stipulated in the BLA. This is a domestic policy inconsistency in that the BLA stipulates empowerment through delegation of bargaining power but the SBSRR does not address this issue at all. It is noteworthy that despite being directed by the High Court, Bangladesh has yet to formalize the SBSRR as an Act, due to a lack of political will and incoherent institutional context (Section 5.5) (Karim 2009).

From the above discussion, we find that international treaties seem to adopt a persuasive approach without coherent capacity building measures, whereas Bangladesh has adopted a coercive approach with implementation challenges. Adopting SBSRR indicates Bangladesh's intention to conform and ratify the treaties. However, due to lack of proper capacity, meaningful compliance will not be achieved. According to Avdeyeva (2007), states often tend to ratify international treaties for two reasons – first, to signal others that it is a compliant nation (Weiss and Jacobson 2000) and, second, due to the minimum requirements required to be compliant with the treaties (Downset al. 1996, Simmons and Hopkins 2005, Von Stein 2005). For developing countries (including Bangladesh), the tension between joining international treaties as expected of a cooperative state, and enforcing the resulting regulations with insufficient capacity and resources, has a profound impact on national-scale policy implementation (Fisher and Green 2004, Najam 2005, Avdeyeva 2007, Pattanayak et al. 2010, Frey 2013).

Coercive compliance will not work without addressing the ship-owner identification issue, as incentives for compliance are currently far lower than the costs of noncompliance (Tallberg 2002). As a result, we might interpret the HKC as a reflection of the signatory parties' desires for the status quo and not an intent to drive meaningful change, as both Bangladesh (as a recycling state) and ship owning countries are incentivized to sign and ratify the convention while remaining meaningfully non-compliant (Von Stein 2005). The status of the international regulatory regime for transboundary movement of waste (especially the HKC and BC) reflects Simmons and Hopkins (2005)'s concerns about treaty effects. They stated that "Treaty effects are merely reflections of underlying state preferences rather than evidence of an independent influence on behavior" (Downs et al. 1996, Simmons and Hopkins 2005). They maintained that treaty creators are primarily focused on the success of the ratification process, and thus often aim for the minimum "depth of cooperation" from the states, requiring the least amount of change for parties to comply.

4.7 Policy recommendations

4.7.1 Deposit refund system

While the HKC contains a large number of standards and restrictions, it does not provide any incentives for nations to become signatories nor for ship-owners and recyclers to comply (Table 1, Rossi 2010). Several interviewees and our review of the existing international and national policies found a significant gap in support for policy implementation in developing countries. For this reason, we recommend adding an incentive program to the HKC, modeled from deposit-refund systems that have been successfully deployed for goods such as beverage containers in most developed countries (Walls 2011). In these systems, a consumer pays a fee at the point of sale for the product, and after use the product's packaging is brought back to be recycled either by the original consumer or by another party; at this point the fee is refunded to the last owner of the container. This system is well-suited to encouraging participation in and compliance with international environmental agreements (Cherry and McEvoy 2013), usually requires the least cost and administrative oversight over other incentive mechanisms (Acuff and Kaffine 2013), and would be ideally suited to the HKC for multiple reasons.

First, the fee would be paid by the first owner of the ship, typically a developed nation or a multinational corporation. These parties have the means to pay such a fee, and can pass the fee on to the ultimate consumers of the ship's services (people purchasing traded goods transported by container ships, or people taking vacations on cruise ships); this is consistent with the polluter pays principle. In this way, the container deposit fee would provide a signal to consumers regarding the impact of their consumption.

Second, the fee would only be refunded when the ship was delivered to recycling facilities in signatory nations that meet the standards described in the HKC.

This would provide an incentive to ship traders to recycle ships in certified yards, and would incentivize developing countries to be signatories to the HKC. Increasing the number of signatories would allow the HKC to come into force, and for the regulations therein to be more broadly enforced across developed and developing countries.

Finally, given that these ships are in operation for decades, the first fee contributions to the system would serve as a source of sorely-needed funds to developing countries to bring their recycling facilities up to HKC standards. These funds could be distributed in the form of grants or low-interest loans, which could be paid back to the fund with profits from the dismantling of the ships. This system would therefore ensure that certified facilities would be available to accept ships by the time the ships in the deposit-refund system reached their end-of-life.

4.7.1.1 Cost Estimate of Deposit-Refund System:

To estimate the costs for upgrading a developing country facility capable of breaking 100000 LDT per year, we used a Litehauz (2013) estimate of a total investment of about $9.5 million USD. For Bangladesh, our study shows that completely dismantling 10000 - 12000 LDT takes about 1.5 months. Thus, the average capacity of a yard will be about 80000 - 96000 LDT per year (8 ships per year). This suggests that about ($9.5/8) $1.2 million USD per ship is required to upgrade Bangladeshi yard facilities within one year. A sensitivity analysis of the cost estimation reveals that in the case of lower costs for concrete and heavy machinery, the total investment may be up to 40% lower for a model facility – which is about $720,000 USD per ship in one year. However, these upgrade estimates include only the introduction of heavy machinery and basic infrastructure in the yard. COWI (2009) estimated the cost at 2,50,000-500,000 USD per ship of a yard capacity of 10000LDT for preclearing and proper hazardous waste facilities. Thus, the total estimate for the upgrade of facilities at a yard in Bangladesh ranges from 0.97 million USD to 1.7 million USD per ship.

The Litehauz (2013) report estimated that this cost can be spread out over a period of five to seven years, where less than 18 percent of the upgrade cost spent in the first year, 30-36 percent spent in the next two to three years, and 50-52 percent spent in the subsequent four years period. Spreading out the yard upgrade cost over four years' worth of ships would bring the per-ship deposit down to $250,000 to $425,000, which compared to the average new price of $58 million per ship of about 10000 LDT (equivalent to 70000 dwt), is a very small fraction of the ship's price (Mikelis 2007; UNCTAD 2012).

In 2007, there were about 42000-45000 transoceanic vessels operating at a time, with a four percent increase every year (Mikelis 2007). This indicates that on an average, 1680- 1800 vessels came into operation per year. On the other hand, average 649 vessel were sent for recycling, ranging from 300 to 800 every year worldwide (Mikelis 2007; Gregson et al. 2010). In Bangladesh, about 30-35 yards can manage the present supply of an average of 200 scrapable ships per year, with a yard capacity of scrapping 8 ships per year (Gregson et al. 2010). To upgrade 35 yards in Bangladesh, a total of $340 million USD would be required (using the high end estimates. A similar cost will be required for India and Pakistan – the two other major ship recycling destinations. Therefore, this deposit-refund system would need to develop a fund worth roughly1020 million USD. If this cost is spread over four consecutive years, in each year, 255 million USD required. And if each year some 1600 ships joined the world fleet, this fleet would need to fund 255 million divided by 1600 ships, which is 0.16 million USD per ship. In sum, the deposit fee should be roughly 0.3% of the purchase price of a new oil tanker of capacity 10,000 LDT/ 70000 DWT.

The amount that every new ship-owner has to pay may depend on the difference between the number of ships joining the world fleet versus the number of ships destined for the scrapping. If there are many more ships being scrapped now than being bought, less money will be deposited for the upgrade fund via the new ships, so it will take longer to upgrade enough yards, given the fixed deposit charged to each new ship-owner. Conversely, if there are a lot of new ships being purchased and few being scrapped, adequate port facilities could be built quite quickly because the deposit fund would be bigger. In the near future, the overall financial situation of the world suggests that the former case is more likely.

4.7.2 Formation of regional recycling states alliance and integrating domestic non-government organizations (ENGOs and domestic courts)

A lack of independent oversight and networking is another issue that has been neglected in both policy development and enforcement. Our interviews and policy gap analysis suggest that there exists a power imbalance during bargaining in international agenda setting, and a lack of a coordinated third-party (e.g., NGOs) network that can provide necessary auditing for state noncompliance. Creating a regional recycling alliance would promote information flows and with it, transparency that will build upon the mutual interests and priorities of the recycling states. This network should be involved in all policy stages, from development and implementation to evaluation. Galley (2014) reported that the domestic legal system (with informational support from the NGOs) detected the illegal import of toxic ships. These networks will emerge as a necessary regional extension of the international regulatory regime to ensure compliance. This dynamic is already functioning in India and Bangladesh informally, as NGOs file lawsuits and the courts are sanctioning the relevant government departments to allow/reject such ships inside the territory (Galley 2014). What we are proposing here is to formalize this dynamic by officially integrating it via the international treaty.

4.8 Conclusion:

Here, we analyze the national and international policies to improve shipbreaking from the perspectives of Bangladesh government officials in regards to compliance with international conventions. Bangladesh has advanced significantly through the Ship Breaking and Ship Recycling Rules of 2011 to improve ship breaking. However, this advancement represents a perfunctory compliance with the international conventions as a political signal to the international community. This is evident when there exists a perceived lack of administrative and institutional competency in terms of manpower, funding, logistics and political will to comply with the conventions. In addition to these internal factors, the perceptions of state officials that the HKC lacks a proper financial commitment toward the developing countries create an obstacle for Bangladesh to be fully compliant with international conventions.

Several mechanisms can be put in place that might secure compliance by the state actors. Tallberg (2002) recommends a combination of both coercive compliance (enforcement) and a persuasive approach to improve state compliance. He maintains that coercive enforcement per se will be misguided if actors do not deliberately seek to violate treaties, but rather are forced to do so by capacity limitations and rule ambiguity. In contrast, the persuasive approach might not work when the cost of shirking is much less than the cost of compliance and the existing liability regime is insufficient to raise the cost of non-compliance.

The work here does not provide insight as to whether Bangladesh will sign and ratify the Hong Kong Convention. Its addition to the HKC depends upon how the other recycling states are responding to its demands. State perspectives suggest two possibilities: it will wait to see if the HKC is improved (including additional regulations on the ship registration system to improve ship-owner accountability, and incentives for financial and technical assistance), or it will sign and ratify following other shipbreaking states but the HKC will remain unenforced domestically so as to be economically less damaging.

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Chapter 5: Conclusions:

Although I am born in Bangladesh, I had never been to these ship dismantling yards before. While reading scholarly articles in the field of industrial ecology, I developed an alternative image of the shipbreaking industry than that I had encountered in the media. I was curious to learn more. For my dissertation, I conducted an ethnographic study with multiple stakeholders including the yard managers, workers, government officials and NGO officials. Most of the interviews were conducted at the yards in Chittagong, Bangladesh during normal operations; while managers were helping to load trucks, workers were organizing scraps and cutters were cutting ships. I spoke with a worker for many hours, sitting down over a bridge in the early part of a moonlit night, listening to his life story about what brought him to Chittagong and what he felt about this work. Despite their vast experience, feelings, and hardships, workers appeared to encounter mainly the views of the NGOs and government officials in the public. As a conscientious researcher, I did not let my perception mingle into the study, but my conscience led me to many of the questions that I asked to different stakeholders.

I am an industrial ecologist trying to promote recycling or reuse of waste and closing the loop. Thus, the effort of recycling end-of-life ships to turn waste into valuable resources gave me a positive impression of this industry and, in balance with this positive contribution, I have tried to assess the argument about environmental contamination and workers health issues put forth by NGOs. In my interviews, I also sought to understand the feelings and experiences of the workers. I discovered the tension the workers experienced when the industry was labeled good or bad. Thus, this study became an effort to delineate the perceptions of different stakeholders. The understanding of the conflict of interest among different stakeholders required a researcher with training in cultural understandings and environmental discourses. Being a Bangladeshi placed me in a unique position, able to unearth the facts about cultural, social and economic underpinnings behind of the ulterior motives of the stakeholders. Thus, my study approach set the tone of discovering the positive contributions of this industry while unearthing the blackspots of the industry as derived from the experiences of the stakeholders.

My chapters are related like a web. My first chapter discusses the social ties and distribution of materials across the country, which connects to the fourth chapter addressing the policy gap in protecting workers and the environment while these materials are processed. The first chapter demonstrates the need for regulation that encompasses the activities of secondary processing of scraps across the country, with similar hazards such as exposure to torch cutting. The second chapter focuses on the causes and extent of impacts from the handling of scraps in several stages beyond the yard cutting and processing. This chapter provides a solid foundation for the third chapter as to why shipbreaking is so negatively presented. The LCA study also provides insight for the policy analysis chapter, identifying the need for more regulations on certain parts of the value chain (e.g., gas torches, rebar rerolling mills).

Chapter three connects to the policy chapter by providing a quantitative analysis of sources of hazards to workers and the environment that policy makers can use to facilitate the international environmental policy regime.

This study will benefit at least two communities: the epistemic community and the Old Dhaka community. The epistemic community should reconsider their position on the sources of environmental contamination in the coastal waters in Chittagong, and reanalyze the services for workers that need to improve, drawing attention to these issues for policy makers and relevant stakeholders. Also, this study highlights how the Old Dhaka community can be better served through improved facilities, technology and training, points of activity for future policy development and implementation.

This study brings to bear another example of the primacy of social factors in the formation of successful industrial clusters. The results recommend more research as to how such social embeddedness can be formed and formalized in addition to the technical necessities of these clusters. I also advance a theoretical challenge to industrial ecology through evidence of accompanying adverse impacts of the recycling/reuse on the recyclers/reusers, giving rise to the argument that the recycling only diverts adverse impacts spatially (from developed to developing countries) and temporally (from now to the future). This suggests a need for industrial ecologists to address future consumption pattern and levels, to resolve issues that fall within considerations of environmental justice and ethics.

The strength of my study is two-fold. First, this study uses two methods unique to the study of end-of-life ships. Life Cycle Modelling has not been used before to evaluate the impacts of the metal scrapped from the shipbreaking yard. Likewise, politics of scale has not been previously used to examine how the distortion of scale occurred during the global dissemination of information about the industry, and how the actors are involved in such distortion. Second, this study highlights the bias inherent to NGO activities and the nature of the local-global network; information conveyed through this network is likely to be biased, partial, and one sided. While NGOs are assumed to be a positive contributor to change in this area, this study has provided dimensions of their activities that need to be addressed.

This study also has weaknesses. First, I could not interview any yard owners in Bangladesh, and thus this study is missing insight from their understanding of this industry. We also could not interview international environmental organizations which largely determine the nature of international environmental governance. Second, this study cannot provide specific policy recommendations regarding industrial symbiosis across industries in Bangladesh, such as the garments industries, leather industries, chemical industries and agricultural industries, which are also key polluters. I hope that future attention can focus on these other industries so that worker safety and environmental protection can be improved across the board in Bangladesh.