Optimisation of Steel Recycling

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Foreword

Written as a business proposal for my submission to the OP Jindal Scholarship requirements, this is a solution that I propose towards a better, cleaner and much more sustainable India. Kindly give this proposal a lot of thought and please provide feedback on limitations and errata that come to light.

Executive Summary

The proposed solution is a **nationwide Smart Steel Recycling Network** that uses **IoT and AI** to enhance the efficiency of steel recycling processes in India. This network will integrate **smart sensors**, **real-time data analytics**, and **automated sorting technologies** to optimize the recycling of steel scrap, reducing waste and promoting sustainability. The solution will use resources that are readily available and will fit right into the current system if implemented correctly.

Background

Steel recycling is a much ignored socio-economic issue in our country. Only 25% of the steel that leaves the factory gates ever reaches back. 75% of all the steel that is produced comes from virgin raw materials[5]. This is an awfully low number with respect to other countries engaged in steel production. There is a very high scope in India to improve this part of steel manufacturing just by tweaking already existing systems. The social aspect of this problem is visible when we look at the pollution that the mining of Iron Ore, Coal and Limestone along with the manufacturing of the steel itself cause. This cannot be ignored as mining causes the displacement of a lot of homes and the destruction of land and nature. On top of this, the dilapidated steel structures that bankrupt corporations leave to rot steal away much required land that could instead be used for building much more useful structures and serve the society.
The Indian steel industry has been characterized by a combination of regulatory requirements, industry standards, government policies, and a growing emphasis on sustainability and technological advancements. The environmental and business costs of iron wastes in India are significant. Addressing this issue requires a comprehensive approach that involves proper waste management practices, pollution control measures, and responsible corporate behavior. By minimizing the negative impacts of iron wastes, businesses can contribute to a sustainable and healthier environment while also protecting their bottom line. The laws that require businesses to have such measures in place are as follows:

- **Environment Protection Act (1986)[2]:** Under this act, steel manufacturers are required to adopt sustainable practices to reduce their environmental footprint.

- **Solid Waste Management Rules (2016)[3]:** Businesses, including steel manufacturers, are required to manage waste responsibly. Recycling steel helps comply with these rules by reducing industrial waste generation.
- **National Green Tribunal (NGT):** The NGT enforces strict regulations on industries, including the steel sector, to control pollution. Recycling steel reduces emissions and waste, helping companies like Jindal Steel avoid penalties.

This also helps steel manufacturers to fulfill their Corporate Social Responsibilities.
Steel Industries in particular would benefit from digitalising their recycling chains due to the following benefits they would be entitled to, thus making it a financially sound thing to do:

- **Energy Conservation**: Recycling steel consumes significantly less energy (about 75% less)[1] compared to producing steel from raw materials. This allows companies like Jindal Steel to reduce their energy costs while also adhering to global climate commitments such as India's National Action Plan on Climate Change (NAPCC).
- **Global Market Demand for Recycled Steel**: There is a growing demand for recycled steel in global markets, especially with countries pushing for greener supply chains. By investing in steel recycling, Jindal Steel can tap into these markets and improve its export potential.
- **Carbon Reduction Goals**: India has committed to reducing its carbon emissions under international agreements like the Paris Accord. Jindal Steel can contribute to these goals by recycling steel, as it significantly reduces CO_2 emissions compared to traditional steel production methods.

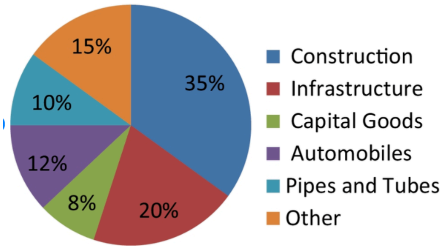
India in particular, can benefit from a digitalised recycling chain due to the immense amount of wastes that are generated in part due to the large population and in part due to the vast amount of industries and building that takes place here.
A digitalised chain would be better than something run by humans because a large amount of data can be crunched fast and action can take place faster. This in turn allows the country to recycle more things in less time. This would also serve to reduce manual labor of people having to inspect every steel structure and every steel vehicle. Instead, this task can be delegated to computers.
In fact, this system that I am proposing can be put into place as soon as possible. If enough action is taken by the companies that supply these materials to builders and manufacturers, recycling can be started in as little as the next 10 years. Almost all finished goods that exit the factory will be available back as raw materials and the company can adopt a **cradle to cradle** approach.

Solution Outline

The solution proposed will consist of the following parts:

- **Tagging** materials that exit factory gates
- **Tracking** materials as they age
- **Retrieving** the materials as they approach the end of their life.

Tagging exited materials



Steel consumption pattern in India. Source: FICCI 2015

We observe that construction and infrastructure consume more than 50% of the steel produced in India.[4] Out of the materials listed, only 'Capital Goods', 'Pipes and Tubes' and 'Other' are the categories that cannot be reliably tagged due to their large numbers and distributions along with the small amount of recoverable iron in each location.

So, we have at least 67% of the consumed steel that can be recycled. This is possible due to steel structures and infrastructure being relatively permanent along with car manufacturers already tagging all of their manufactured cars. This tagging can take place when the deal to procure such steel occurs. Tagging can take the form of including ***smart strain gauges*** *on buildings and infrastructure. It can take the form of monitoring the odometer reading on cars and other automobiles including trucks. Trains can also have strain gauges installed.*

The function of these strain gauges is to get strain data on the structures that they are installed in and redirect them back to a central processing server running on the cloud. The cloud will be responsible for storing this data long term and running data analytics on them.

In addition to this, these huge permanent structures will be geotagged and satellite tracking can be used to detect their dilapidation even if the strain gauges fail in due time. Satellite data is very abundantly available due to the Indian government investing heavily in Geostationary Mapping satellites. This geotagging will help our data crunching servers to track the color and structure of these places over time and determine when the right time for retrieval occurs. This can be accomplished using pre-existing CNN models that just have to be trained on previously available data.

Tracking aging materials

When a certain threshold of steel sold to a particular company exceeds a particular limit, the company should be mandated to add IoT sensors to certain locations on the infrastructure that gauge and judge the quality of steel and the strain that it bears over time. When a theoretical limit is reached, these sensors should alert both the company that built it and the manufacturer of the steel regarding the need for replacement. These sensors can take the form of cheap IoT boards that run on low power which also have bluetooth or WiFi connectivity to connect to the internet to send data. The financial analysis of procuring such electronics in bulk is provided in the Financial Forecasting section of this document. A generalized description of such electronics would be to use a board such as the ESP series of IoT boards that can have a lot of sensors attached to them. A single board can monitor multiple sensor outputs which guarantees much lower costs in terms of initial investments as well as maintenance costs as these boards are incredibly low power and can handle internet communication easily.

With respect to cars and automobiles, the already existing telemetry systems can be modified to send the odometer readings of the automobiles to the steel manufacturers.

The criteria that can be used to judge the lifespan of such structures and automobiles will be based on the ***fatigue and creep strength of the steel****:*

- *Fatigue can be monitored by checking the number of loading cycles that the steel experiences. Once this crosses a predetermined limit, the company can warn the consumers regarding the imminent failure that they may face with regards to the structure they own. The parts that have these issues can be replaced and the steel that is retrieved can be sent back to the factories to be made into new steel, as described in the next section.*
- *Creep strength analysis can be conducted based on the strain data along with the basic analysis of stress-strain data using load cells that can also be added where necessary.*

These components can be produced in bulk and come cheap and the IoT chips can also be made pre-programmed from the factories making the whole system plug and play in nature.

This tracking can also take place using satellite image data that tracks geotagged locations for signs of rusting and dilapidation. This could be done using neural networks trained to detect this kind of dilapidation. The data for training can be gathered from old buildings that are in the state that we require and old satellite imagery can be used to see how they changed over time.

Retrieval systems

This is the most important and most resource intensive part of this whole procedure. Setting up collection centers near railway stations all across the country using the same lines used to deliver the steel is a solution that serves well. When the steel is delivered, the train carriages have to go back to their destinations with no load to carry. We could use these empty trains that are guaranteed to handle large quantities of steel to carry back our scrap metal to the manufacturing location. This ensures that we don't have to make new infrastructure for transport of scrap from the location where they are generated.

There will also be processing centers for such kinds of steel that will be set up which will process the steel that it receives from flagged structures that have been collected and sent to it. There will be dedicated vehicles that each such plant has which will be responsible for the scrap collection.
The collection system will follow a cluster based architecture. We will create clusters of such collections centers and processing plants around high load areas such as chemical industries, petroleum refineries and train making factories where steel wastes are high and start collection. The companies will be responsible for getting the artifacts that they sell back to their factories and storing them until the processors can take them back. The rest of this is just a supply-chain problem that can be solved using conventional means of management.

Benefits

*This system offers several key benefits by leveraging advanced technologies and efficient processes. Through the use of **smart strain gauges, geotagging, and satellite tracking**, it enables **efficient tracking of steel structures**, making it easier to monitor their aging process and determine the right time for replacement. This leads to **improved infrastructure maintenance**, where regular monitoring ensures timely replacement of worn-out steel, preventing accidents and structural failures. Additionally, **advanced dilapidation detection** through satellite imagery and neural networks offers an extra layer of security, even if physical sensors fail, by identifying rusting and deterioration in real time.*

*The system's **cluster-based collection and processing** strategy enhances the efficiency of scrap steel recovery, especially in high-load areas such as chemical industries and refineries, ensuring that steel waste is collected and processed in an organized manner.*

*The **long-term data storage and analytics** provided by the cloud-based architecture further strengthens the system, allowing for advanced analytics and forecasting that can optimize maintenance schedules and resource allocation. This also allows a lot of data collection for research aiding to create better steel with properties tailored to particular industries.*

*Ultimately, this system promotes a **reduction in steel waste** and supports a circular economy by ensuring the recovery of steel from structures and automobiles, minimizing environmental impact and conserving valuable resources.*

Limitations and Risks

*The proposed system faces key challenges in **data privacy, scalability, and environmental factors.***

Data Privacy and Security Concerns

*Cloud-based data storage introduces risks of **data breaches and cyberattacks**, while continuous monitoring may raise concerns about **privacy violations** for vehicles and sensitive infrastructure. Dependence on **government satellites** also poses a risk if satellite access or data availability becomes restricted.*

Scalability Issues

*The system may be harder to scale across **smaller industries** due to economic feasibility, and expanding it globally would require navigating complex **legal and regulatory hurdles.***

Environmental Factors

***Harsh weather, corrosion, and physical damage** could affect the performance of IoT sensors, leading to **inaccurate readings or failures**, particularly in extreme environments. These factors could increase maintenance costs and compromise system reliability.*

Financial Forecasting

Equipment and infrastructure cost list:

- Estimating the cost of the devices themselves, accounting for bulk manufacturing would come to **₹100-200 per board** and sensor combination[6].
- Based on limited public data, a rough estimate for a medium-sized scrap steel preprocessing plant in India could range from **₹50 crores to ₹200 crores**[7][8]. For our purposes, let us take the rough estimate to be around **₹100 crores** per plant.
- Maintaining this plant would take around 5% of the initial investment cost per annum. A valuation of around **₹5 crores.**
- Computation and cloud infrastructure to manage data would cost[9] close to **₹2 crores** per annum considering 0.1PB of data to be stored on an S3 Bucket along with m5.48xlarge instance for data analytics.

Estimating bulk costs:

- Estimating that we service a total of 30% of steel produced per annum,
  125.32 million tonnes*30% = 37.597 million tonnes. Assuming that every 10 tonnes of steel requires a single device,
  37,59,600 devices would be required accounting for a total of around **₹37 crores** per annum.
- Considering that India has around 500[10] major steel consuming hubs, 500 such plants should be set up, with a total upfront cost of **₹50,000 crores** and maintenance costs of **₹2500 crores** per annum.

Results:

- Upfront costs: **₹50,000 crores**
- Yearly maintenance: **₹2500 crores + ₹2 crores + ₹37 crores = ₹2,539 crores**

Estimating the costs saved by recycling:

- Estimating a total of 30% production costs saved per tonne of steel produced[11].
- Estimating that every ton of steel produced costs around **₹65,000.**
- Keeping in mind the total steel we are considering- 38 million tonnes, the total costs saved per annum will be
  38 million * (30)% * ₹65,000 = ₹7,41,00,00,00,000 which is **₹74,100 crores saved per year.**

Final Conclusion

- We can turn in a profit of around **₹21,561 crores** in the first year of starting this system and a subsequent profit of **₹71,561 crores** in the subsequent years.

  Of course, this estimate is just that, an estimate. But, please notice that the system proposed is almost guaranteed to turn in a profit due to the sheer amount of savings from the recycling of the steel.

Issues with the financial forecast:

- Labour costs not taken into account
- Accurate data was not available, so in some places, guesstimates have been made.
- Transportation costs are not taken into account.

Citations

[1]:https://worldsteel.org/circular-economy/

[2]:https://www.indiacode.nic.in/bitstream/123456789/4316/1/ep_act_1986.pdf

[3]:https://cpcb.nic.in/uploads/MSW/SWM_2016.pdf

[4]:https://www.researchgate.net/figure/Steel-consumption-pattern-in-India-Source-FICCI-2015_fig2_363764608

[5]:https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1906444#:~:text=The%20overal%20utilization%20of%20the,of%20the%20input%20material%20used.

[6]:https://resources.pcb.cadence.com/blog/2023-10-factors-in-pcb-fabrication-cost-estimation

[7]:https://documents1.worldbank.org/curated/en/373381637134437311/pdf/Final-Fiduciary-Systems-Assessment-Rejuvenating-Watersheds-for-Agricultural-Resilience-through-Innovative-Development-P172187.pdf

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